Report of the
Earth Observing Missions Applications Workshop

February 1–3, 2010
Colorado Springs, Colorado

November 4, 2010

Dear Colleague,

NASA's Earth Observing Missions Applications Workshop was held February 1-3, 2010 in at the Colorado Springs Marriott, Colorado. The purpose of the workshop was to further develop the application goals, objectives, and needs, as well as provide traceability to the missions and required observations and measurements. The goal was to engage the applications community early in the mission design and development processes, allowing for better preparation to manage the data from the missions, and to develop rapid and useful response products. The existing missions have demonstrated the value of NASA research measurements to operational users, while upcoming missions provide the opportunity to balance the science, applications and response objectives of the missions. For the missions already in development, the degree to which applications needs have been integrated into the mission implementation varies and needs to be evaluated. The workshop provided a forum to explore lessons learned from the EOS and technical challenges to achieving the application goals. Roles and responsibilities of users and other agencies as well as their interfaces into the missions were discussed. This workshop is considered the first in a series of dialogues to maximize the return and minimize the cost of future missions for our national interest.

Sincerely yours,

Workshop Conveners

Organizing Committee

Table of Contents

Executive Summary

NASA's Earth Observing Missions Applications Workshop was held February 1-3, 2010 in Colorado Springs, Colorado. Attendees of the workshop included representatives from NASA Earth observing missions, the data user community, data centers, and academia. The purpose of the workshop was to further develop the application goals, objectives, and needs, as well as provide traceability to missions and required observations and measurements.

Existing missions have demonstrated the value of NASA research measurements to operational users, while upcoming missions provide the opportunity to balance the science, applications, and response objectives of the missions. The workshop provided a forum to explore lessons learned from previous Earth observing missions and technical challenges to achieving the application goals.

The workshop was the part of an ongoing effort by NASA to better engage the applications communities early in the mission design and development processes. It was the first in a series of dialogues to maximize the return and minimize the cost of future missions for our national interest. There were 143 registered participants in the workshop from several agencies, non-government organizations, states, academia, and, industry. Recommendations developed at the workshop address strategic, organizational and data aspects of improving end-user engagement in missions:

- Strategic
- Accelerate use of NASA data for applications and societal benefit
- Develop and maximize government, private, and academic partnerships
- Organize around grand challenges in areas to be determined
- Leverage Existing activities
- Organizational
- Integrate applications users into mission teams as early as possible
- Conduct periodic user meetings and encourage more frequent interactions of subgroups and agency partners
- Train the next generation
- Data
- Ensure data continuity
- Improve infrastructure to provide access to high level data products
- Improve infrastructure to provide rapid access to data

Spaceborne technologies provide data for the Earth that are of utility for improving scientific knowledge as well as for operational applications. The data become of greater utility for applications as the observations and/or scientific understanding is improved. In 2007, following a request from NASA, NOAA, and the USGS the National Research Council published a report entitled "Earth Science Applications from Space: A Community Assessment and strategy for the future," better known as the Earth Science Decadal Survey [1]. The decadal survey group was to generate consensus recommendations from the science and applications community for a systems approach to conducting space-based and ancillary observations that address both the research and operational communities. The report recommended 17 missions. Meeting these applications objectives requires systematic scientific research.

The primary objective of this workshop was to identify and catalogue current application usage of data, concepts for future applications use and implications of such usage, and common needs across disciplines. NASA will consider these application needs along with the science requirements identified by NASA under a separate activity. Results from this and other workshops and discussions will inform NASA on themes that could enable NASA to rapid and useful products for a broad range of applications and users.

Future workshops can be used to more clearly define participants from the applications community as well as to identify any additional commitments that may be needed to meet the applications goals. Specific questions were asked of the workshop participants during breakout sessions and applications were divided into these areas:

- Agriculture
- Air Quality
- Disasters
- Ecological Forecasting
- Public Health
- Water Resources
- Weather

Climate was considered in each application area and there was a plenary discussion on climate at the workshop. Climate was integrated into all discussions given that it is an aspect of all disciplines.

This workshop is a starting point for community engagement and is intended to identify those applications of high societal benefit and with high probability of success. The workshop focused on identifying the goals and objectives for each application, the observational needs, the desired data products, targets of interest, and response plans.

Identification of Obstacles to Using NASA Data

The meeting began with a panel discussion of potential users of NASA data. The goal was to identify the biggest obstacles at present to using NASA data. Participants included representatives at agency, state, and non-government levels.

Application Objectives and Needs within Existing Mission Descriptions

Needs Cutting Across All Missions

Recommendations

Key Findings

1. Strategic

    a) Accelerate use of NASA data for applications and societal benefit.

    b) Develop and maximize government, private, and academic partnerships.

    c) Organize around grand challenges in areas to be determined.

    d) Leverage existing activities

2. Organizational

    a) Integrate applications users into mission teams as early as possible.

    b) Conduct periodic user meetings and encourage more frequent interactions of subgroups and agency partners.

    c) Train the next generation.

3. Data

    a) Ensure data continuity.

    b) Improve infrastructure to provide access to high level data products.

    c) Improve infrastructure to provide rapid access to data.

1. Perspectives from the User and Mission Communities

New technologies developed by NASA and open data policies have enabled the uptake of data for new applications. The Earth observing satellite data have enabled a dramatic improvement in our understanding of many areas including environmental change, weather, hazards, air quality, hydrology, public health, and more. The civil engineering community is also gaining interest in applying remotely sensed data to work related to civil infrastructure.

Conservation non-government applications include forest carbon estimates, Reducing Emissions from Deforestation and Forest Degradation (REDD) monitoring, reporting, and verification, tracking and modeling climate variability and change, and assessing and valuing environmental services such as water, biodiversity, carbon, and clean air. These organizations work primarily in countries in the tropics where cloud cover, lack of ground-truth data, slow Internet download speeds, and low technical capacity pose major challenges. Remotely sensed data provide systematic observational access to poorly accessible regions. Widely used data come from Landsat, ASTER, MODIS, TRMM, SRTM, MOPITT and from external data sources such as AVNIR, PALSAR, and LIDAR.

1.1 Challenges to Using NASA data

NASA is a research organization, and as a result the primary focus of data product development and utilization has been the NASA organization and experts at universities. Originally, there was not an emphasis on serving the needs of a wide range of end-users, who might have a wide spectrum of capability to work with complex, un-digested data products. Challenges include low-level or raw data products that require an expert to analyze and lack of standardization and the distributed nature of data centers.

1.1.1 Data Location and Access

NASA's Distributed Active Archive Centers (DAACs) provide a valuable scientific resource, but are not set up to specifically address application user needs. The organization and location of data in the DAACs regularly change. More continuity is needed for the DAACs to be an adequate resource for applications communities. Minimize delays in processing or lowering the latency from data acquisition to product availability is important for operational use and real-time applications.

Search engines are not reliable for location data and terminology for searching for data can be complicated. Experienced users understand the subtle tricks required for finding data through the DAACs, but the search interfaces must be more user-friendly to accommodate less frequent and experienced users. As an example, the Global Visualization Views, GLOVIS, can be used to search for available data. GIOVANNI has been developed for atmospheric measurements. As a next step, however, the user must order the data through Explorer or through a DAAC.

Greater interaction between the interface developers and those who download and use the data, including the infrequent users would improve the user interfaces. NASA should consider establishing user groups to facilitate development of user interfaces that make NASA data easily accessible and useable.

NASA data provide a valuable national resource due to the open data access policy. Non-Government and other organizations do not have the financial resources to buy expensive data. Freely available data make it possible for both science users and applications to explore and experiment with data for both current and future applications.

1.1.2 Data Formats and Resolution

NASA provides a valuable service to user communities through data standardization. GeoTIFF is one of the most widely accessible data types. HDF is good for inclusion of metadata. NASA will build a larger community of data users by avoiding frequently changing formats and by developing and supplying tools to read the data formats.

High precision data products are preferred, particularly for the scientific communities; however end-users often would prefer lower resolution quick look products to higher resolution products that take longer to deliver. The immediate need for information, particularly in disaster response, overwhelms the need for higher precision or resolution.

Spatial resolution

Higher resolution data are usually preferred; however, even low resolution can fill in data gaps for regions where data would be otherwise unavailable. Systematic acquisition is preferred over targeted acquisition and has the effect making the data more routine and accessible.

Spectral resolution

At present many applications only require Visible or Near-Infrared (VNIR) spectral bands. Mid-IR and blue channel in Landsat are important for spectral mixing analysis (not available in many 4-band sensors). IR data can also be used for other applications such a mineral mapping or fire hotspot detection. Light Detection and Ranging (Lidar) can be used to provide precise elevations of topography, buildings, and vegetation, while radar can provide scattering characteristics or interferometry for determining motions of the ground or infrastructure. As higher-level data become more accessible, available wider use of more spectral bands and techniques will occur. Developing a community that provides the translation between the low-level data products and the user communities will be important to increasing the utility of NASA data.

Temporal resolution

Required temporal resolution is dependent upon the phenomena that is being observed. For monitoring annual updates will often suffice. However, in areas with seasonal signatures semi-annual or seasonal measurements are required. For rapid changes, such as for monitoring disasters, measurements on a daily scale with less than two-day data product latency are needed.

Geometric accuracy

It is recommended that geometric accuracy be a strong focus for future data acquisitions or mission designs. Users currently spend much of their time georeferencing data. Future instrument acquisitions should have coverage areas that are aligned and matched to facilitate multisensory data fusion and analysis.

1.1.3 Derived Products and Validation/Calibration

Providing higher-level data products, whether by NASA or by an external entity will increase the utility of NASA data. It is also important that the data be calibrated and validated. Coordinating observation strategies and target areas between NASA observations and other entities will improve data calibration and validation. This is important for understanding the NASA data for all regions, but provides calibration for regions where only the spaceborne or airborne data can be collected.

1.1.4 Data Continuity

A key issue identified by the user community is the need for data continuity. Using new data types requires training of personnel. If data are discontinuous or if missions are of only a few year duration the user community is reticent to invest the time and money into learning to use the new data products. Data gaps also pose a problem when user entities come to rely on those products for policy and decision-making. Addressing this issue requires a plan and funds to transition NASA capabilities to operational agencies.

1.2 Perspectives from previous missions

EOS and other missions provide lessons learned and perspectives on using NASA missions to address applications needs. MODIS, TRMM, and OMI instruments/satellite have been the "work horse" of Applied Science research. Sensors of these types will continue to have high science utilization. Direct Readout capability has been a tremendous contribution to the world community for studying disasters and other applications and building capacity.

Having an open data policy allows for development of applications using mission data that weren't necessarily envisioned at the outset of the mission. NASA is the only Agency with an open data policy. However, the open data policy is not well publicized. There is no "cookie cutter" solution to addressing societal problems. Applying science data to applications or applied research will continue to be a challenge. Commercial high-resolution data can often be augmented with NASA data products.

Engaging partners from the beginning is key to successfully applying mission data to applications. A strong partnership was established with ESA, JAXA, INPE, CONAE, and CNES during the EOS era. NASA must continue the tradition of sharing mission development cost. EOS also benefited from engaging the National Academy and the user community. EOS was reviewed by the National Academy and also had frequent external reviews.

Technology development should also focus on technology infusion. There are numerous technology developments underway within NASA. Every effort should be made to take advantage of these development efforts and infuse them into the decadal survey missions. NASA should consider making this a mandatory requirement to the proposer.

Program management structure should also be considered when addressing user needs. EOS had a comprehensive project management structure. The structure was effective for addressing application needs and the decadal survey missions should consider a similar structure. Components that need to be addressed and can be guided by an appropriate management structure include:

- Level I requirements, including gap analysis and reducing mission overlaps
- Overall program plan
- Implementation Strategy/plan
  - Technology Infusion Plan
  - Data System Concept and Architecture
- Project management plan (including Centers)
- Science Utilization Plan

1.2.1 Applications Successes and Challenges

Much has been learned from the Earth Observing System (EOS) missions and their associated data systems. Two data systems, or data strings, are needed. One is to deliver best quality research products and the second supports near real-time (NRT) application products. Often users will sacrifice data quality for data timeliness. The latency of production of ancillary data can drive the latency for the primary data product.

Custom products are often needed to meet specific user needs. For example users may require specific GIS formats that interface with existing application systems. Map projections, composting time periods, data subsets and key examples needs for applications users.

MODIS Rapid Response

The MODIS Rapid Response provides daily images of the landmasses of the Earth in near real-time. Moderate Resolution Imaging Spectroradiometer (MODIS) flies on both the Terra and Aqua satellites providing morning and afternoon imagery in true-color, false-color, and photo-like imagery. MODIS rapid response products are used for monitoring fires, crops, growing conditions, dust, and air quality. Often clear imagery is adequate. MODIS Rapid Response was developed in conjunction with the applications community. It provides a model for development of missions for addressing applications needs.

Application users need to have plans to move from a successful prototype to robust operational capability. Sustaining engineering is needed. Application users should participate in the evaluation of improved products. It takes time to build many new applications, requiring adequate and often long lead-time to understand the needs and develop applications systems.

Weather Applications

Weather applications have a need for day and night observations, atmospheric and surface (land and ocean) conditions and products that help diagnose current weather conditions or help predict future state of atmospheric and surface conditions. Products are needed at the highest resolution possible. Data must be timely, accurate, easy to understand and use, and available in a variety of formats for users to ingest into their decision systems. Users need help using the information, and as such partnerships must be developed from the beginning. It is not effective to simply throw data over the fence to the users.

Addressing user needs often adds additional demands on missions. For weather and other applications the missions need to provide access to real-time data. Doing so requires direct broadcast of the data from the satellite. A suite of products must be readily available (in real-time) to address weather needs. Most users don't have knowledge or resources to produce their own data products. Production algorithms should be linked to real-time data sources. Science algorithms must be validated and proven if they are to be used in end products.

End users require not just images, but the digital data as well. Delivering the data to end users must be supported by real-time data and product "warehouse" and distribution systems such as CLASS or LANCE. Data should also be available in a variety of formats such as netCDF, KML, etc. Subsetting tools reduce data volume or changes coverage region. Subscription services for rapid products that push data make it easier for end users to utilize the data.

1.2.2 Example: Transition to Operations with the National Weather Service

The Short-term Prediction Research and Transition (SPoRT) project transitions EOS data to the operational weather community to improve short-term weather forecasts on a regional and local scale**.** Transition products include real-time MODIS and AIRS data and near real-time AMSR-E, CloudSat and other EOS products. The data are matched to the forecast problems and integrated into operational decision support systems.

Evaluating the impact on forecast process and decisions will ensure the usefulness of NASA mission data products. Proving the capabilities allows for the capabilities to be transitioned to other organizations such as NOAA, the National Weather Service, and the private weather sector for operational use. Infusing NASA mission data into operational systems prepares forecasters for next generation satellites and NOAA will build with NASA input, and ultimately saves lives through better preparedness and warning.

2. Partnerships

NASA is heavily involved in the development and operations of Earth Observing Missions. Because NASA is a research agency most of these missions have a research focus. However, there are numerous applications these missions can address and effective partnerships will maximize the utility of civil remotely sensed data. Effective mission collaboration between NASA, NOAA, USDA, and the USGS, for example, can best serve the Nation's needs for innovative and reliable use of space-based observations. Over the long term, applications communities can best be served with a strong research program followed by assured long-term operational continuation.

2.1 Balancing science and applications

Because NASA is a research agency, the science needs of missions must take priority for NASA. However, development of common infrastructure, standards, or formats, can leverage NASA data for end user. NASA is seeking input on and considering ways to improve infrastructure such as direct broadcast for real-time use of data.

If missions are to meet end-user needs, it is also appropriate for end-user agencies and groups to partner with NASA in development and cost sharing. Developing effective partnerships requires organizing together early in the mission process. An applications plan as part of the mission development documents would facilitate the process. Memoranda of understanding define and clarify roles and contributions.

2.2 Types of Partnerships and their Roles and Responsibilities

May different groups can make use of NASA data and may have different needs as well as differing abilities to contribute to the NASA missions. In developing partnerships NASA should consider the following:

- How can the organization contribute and what role would they play for their application(s) of interest?
- What financial requirements are there to meet the organization role? Does the organization have the resources to meet the requirements?
- Are there restrictions that would be placed on the data quality or distribution by other agencies?

Because end-user applications needs may be different than science needs requirements creep must also be considered. Requirements creep can add complexity and increased costs to missions. If additional requirements are levied on the mission it is often appropriate to have an end-user agency or organization share in the additional costs.

Partnerships and MOUs established early in the mission smooth development and are more likely to result in a mission design that satisfies user needs.

2.2.1 Partner Organizations

Several types of organizations can partner with NASA to meet user needs. These include:

- Federal agencies
- State and local governments
- Non-government organizations
- Philanthropic organizations
- Industry

Federal agencies have a national view and have specific directives or goals and objectives that may be addressed by spaceborne missions. Other agencies can more easily make long-term commitments than other types of organizations. Agencies often have research and development arms that make it easier to transfer the capabilities.

Other organizations such as state and local governments or industry often have immediate needs or smaller budgets that make it difficult to develop long-term investments. State and local governments as well as another agency pointed out that for operational use long continuous data sets are important. They are unlikely to invest in the training needed for using new capabilities for missions of short duration. While NASA may not have sets of data that are continuous or are long-term of one type, it is possible to produce data streams of different characteristics but for addressing some us that can be fused into a long-term and or continuous data type or parameter.

Non-government organizations often have smaller budgets and cannot partner directly in mission development. However, if NASA can add value at low cost, or partner with other agencies to produce user data products they should consider doing so. Industry similarly tends to take advantage of data in the public domain or that are easy to integrate into end-user products. NASA’s open data policy spurs innovative uses of NASA data. It is important to close the feedback loop so that future missions can be optimally designed for a variety of uses.

Example: New Partnerships between NASA and NOAA

Consistent with the National Space Policy, Congress has directed NASA and NOAA to collaborate on Research to Operations (R2O). Joint NASA-NOAA transition plans are to be developed and submitted to Congress. Transition plans are needed for many NASA satellites, ranging from aging but operational satellites to most Decadal Survey missions.

NOAA has a mission which requires establishment and sustainment of long-term operational services. As an operational services agency, NOAA’s funding processes are slow and deliberate. NOAA’s decisions are for the long-term, as services that are started are rarely terminated. Furthermore, building operational-quality satellites is even more expensive than research satellites and often includes redundant on-orbit spare satellites. NOAA is also a part of the Department of Commerce and must compete for funding with other elements of the Department. This makes NOAA's decision processes leading to a new satellite commitment very difficult.

NOAA has strengths that may be able to contribute to the broader application community's needs. NOAA has extensive ground assets for the receipt, distribution, processing and application of satellite observations. When decreased latency or enhanced global coverage is an important driver, NOAA can explore ways to leverage existing assets to reduce product delivery time. NOAA has extensive connections with end-users including Regional teams which maintain good connections with States and local agencies. NOAA also has an extensive requirements database which may help NASA connect mission possibilities with user needs.

David Hermreck, NOAA

3. Recommendations

Several recommendations flowed out of this workshop, which fell into three broad categories. These were 1) strategic, 2) organizational, and 3) related to data. Key recommendations for those three areas are as follows:

1. Strategic

    a) Accelerate use of NASA data for applications and societal benefit

    b) Develop and maximize government, private, and academic partnerships

    c) Organize around grand challenges in areas to be determined

    d) Leverage existing activities

2. Organizational

    a) Integrate applications users into mission teams as early as possible

    b) Conduct periodic user meetings and encourage more frequent interactions of subgroups and agency partners

    c) Train the next generation

3. Data

    a) Ensure data continuity

    b) Improve infrastructure to provide access to high level data products

    c) Improve infrastructure to provide rapid access to data

3.1 Strategic

3.1.1 Accelerate use of NASA data for applications and societal benefit

- Assess user needs by mission and application
- Identify common user needs by mission
- A data product or implementation mode may serve multiple user groups
- Identify common user needs across the missions
- Infrastructure may address multiple user group needs
- May result in improved data continuity, availability, or quantity
- Encourage active participation and investments by the end users

3.1.2 Develop and maximize government, private, and academic partnerships

Government

- Policy, science, engineering
- Planning and administrative/service linkages
- Link all scales from municipalities/counties to states to federal

Private

- Engineering
- Value-added service business
- Innovation/start up companies

Academic

- Incorporate academic institutions early on in the development process working side-by-side with industry to develop products
- Science, engineering
- Urban planning, public administration
- Student and early career source
- Leverage academic programs with strong remote sensing curriculums – creative internships where a year of grad school is paid for in return for 2 years at an agency.

Link Users

- Link users at all scales
- Active interagency cooperation
- Incorporate end user organizations and individuals from the start
- Working partnerships provide the most promise for long-term transitioning of advanced approaches to end users
- Create in-residence, remote assignment, and exchange programs as a means of transferring knowledge and fostering partnerships
- Formalize partnerships with MOUs and MOAs
- Incentivize joint partnerships
- Encourage investments by the end users
- In kind
- Financial

3.1.3 Organize around grand challenges

Addressing grand challenges focuses efforts and brings together multidisciplinary users to address themes of national importance. Organizing around grand challenges focuses efforts on items of national importance bringing together and integrating the mission and user communities. Integrated mission and user communities enforces consistent integrated higher level data products.

Examples

- Rebuild and protect our nation’s infrastructure (TBD)

    - Carbon cycle and climate (TBD)
        - Understand climate forcings and impacts
        - Provide information for treaty monitoring
- Understand and respond to disasters
    - Provide hazard and disaster information where and when it is needed
    - Understand the natural processes that produce hazards
    - Recognize vulnerability of interdependent critical infrastructure

3.1.4 Leverage existing activities

- Don't reinvent existing activities
    - Work within existing partnerships if possible
- Inventory and participate in existing activities and partnerships
    - Many of these already exist
    - Not described in one place for NASA
- Identify all levels of activities
    - International activities
    - Federal committees/activities/partnerships/plans
    - State organizations
    - Municipalities

3.2 Organizational

3.2.1 Integrate applications users into mission teams as early as possible

- Ensure applications mission representation
- Participate from pre-formulation through operations
- Representative(s) would draw on broader user community
- Member's time supported by agency/user organization
- Meet as a group to understand how mission would meet the user needs
- Semi-yearly to bi-yearly meetings in conjunction with science and mission team.

3.2.2 Conduct periodic user meetings and encourage more frequent interactions of subgroups and agency partners

- Continue dialogue through an interagency working group
- Convene as soon as practical
- Convene periodic broad user meetings
- Convene meetings coincident with other standing meetings
- Encourage working groups and mission teams

3.2.3 Train the next generation

- Incentivize early career participation
- Fellowships
- Grants
- Develop student programs
- Shared graduate students
- Student fellowships
- Student internships
- Develop career paths that bridge the gap between advanced technology and operational use of spaceborne data.

3.3 Data

3.3.1 Ensure data continuity

- ***Data continuity was the biggest concern expressed by the end users***

- Adopting new approaches requires a substantial investment by the end user organization. NASA should assist in the "buy down" of this cost in the case of state and local governments.

- Our nation must adopt a new paradigm to ensure data continuity

- As an agency NASA should

    - Develop advanced concepts, technologies, and missions to

        - Understand natural processes that impact our home planet

        - Provide a synoptic view on global, regional, and local scales using spaceborne and airborne assets

        - Once a measurement has proven to be valuable NASA should assist the transition from science measurement to commercial service or to and operating agency with responsibility for providing that measurement.

    - Provide information as available when and where it is needed – The use of the words "as available" is directly opposite of the idea of continuity

- Other agencies must deploy operational missions or partner with NASA to insure a smooth transition from science validation to operational use. Other agencies do not have the infrastructure to deploy missions and NASA does this very well. The federal government should reach agreement on roles and let NASA do what it does well and also allow the other agencies to do what they do well.

- Improve infrastructure to provide access to high level data products. NASA data is difficult to impractical to use for non-team members.

3.3.2 Improve infrastructure to provide rapid access to data

Data quality information

- Metadata standards to bridge the gap between data and scientifically useful information.
- Data discovery, mining, fusion, and registration is needed to make the right users aware of the right data sources.
- Services to allow users to create the products they need (transformations like subsets, accurate geo-referencing, fusion of very diverse sensor data, etc).
- Spatiotemporal information services for compositing models.
- Automated notification of availability and data delivery.

Visualization tools

- Easy to incorporate products into decision support systems or field displays

Data latency – the demand for 'good-enough' data for emergency response

- Quick look products
- Define latency thresholds <30min, <3hrs, <48hrs
- Determine options and trades between:
- Onboard processing
- Direct broadcast
- Web-based services for routine products
- Regional processing services for community-specific products

Other recommendations include:

- Increasing temporal resolution
- Acquire complementary sensor measurements
- Reduce response time
- Automatically respond to detected events
- Develop direct downlink capabilities

3.4 Challenges

- Existing bureaucracies

- Disparate funding at local state and federal agencies

- Funding cycles differ

    - Getting in lock-step takes years
- Discontinuous datasets
- Education and training
- Programs that are solicitation-based and as result have a fragmented impact on any single issue or potential user community

3.4.1 As an Agency NASA Should

- Through an interagency process determine the next best measurement to make, employ its proven methods to develop the technology, launch the mission, validate the measurement, and assist in the transition to operations.
- Develop advanced concepts, technologies, and missions to:
    - Understand natural processes that impact our home planet
    - Provide a synoptic view on global, regional, and local scales using spaceborne and airborne assets
- Support Other Disciplines as End Users
    - NASA products do not only serve the science communities
    - For a strong economy and high quality of life many disciplines need to be using advanced remote sensing measurements
        - Engineering
        - Public Administration/Planning
        - Geographic Sciences
- Many of the users come from engineering rather than science disciplines.

3.4.2 Partner Agencies Should

- Invest in aspects of the mission that specifically benefit that agency.
- Support participation of staff in mission applications working groups.

3.4.3 Addressing the Challenges: Maximizing Investments

- Incentivize partnerships
    - Joint solicitations
    - Cost sharing
        - In kind – salaries/time

        - Financial – transfer of technology
- Incorporation of early adaptors
    - Bring in key liaisons for communities to bridge organizational barriers
    - Inertia is difficult to overcome
        - Resistance to new technologies and methodologies
- Train our next generation
    - Involve early career scientists and engineers
    - Develop internships, fellowships, shared-student programs
        - Potential to be hired into user communities

3.4.4 Metrics: Assessing Effectiveness

- Evaluate end user adoption
- Quantify acquisition of instruments or assets
- Assess whether adopted on a long-term basis or tried and discarded

4. Applications

Applications in addition to climate discussed specifically are:

- Agriculture
- Air Quality
- Disasters
- Ecological Forecasting
- Public Health
- Water Resources
- Weather

While each application has its own specific issues there are also cross-cutting issues, which are discussed in a later chapter.

4.1 Agriculture

The overriding topics of interest for agricultural applications were agriculture, forest and climate change. Specific areas of interest under that topic included monitoring of agricultural land for crop type identification, production and yield estimates, drought management and characterization, presence and spread of invasive species and crop pests and diseases; range land and forest land inventory and management; crop/vegetation water usage, soil moisture content, evapotranspiration; impact and mitigation of disasters including fires and floods; development and use of tools for agricultural monitoring from space and input to crop models (e.g. data for rainfall, solar insolation and temperature); and assessment of the manifestation of economic factors on agricultural land. Information products from spaceborne observations can be used to improve monitoring, modeling and prediction for these topics of interest described (Table 1).

Table 1. Information needs for monitoring, modeling and prediction for agricultural applications

Monitoring	Modeling	Prediction
Water content of soil and crops	Yield and growth models	Production, yield, area
Aerial extent and classification	Evapotranspiration	Change in yield and production
Crop phenology	Root zone soil moisture	Food prices
Crop residue cover	Climate	Weather and climate (annual, interannual, seasonal predictors
Crop and natural vegetation	Carbon flux	Land/climate suitability

water use (ET models)		
Disturbance e.g. fires and floods	Ambient temperature	Water availability and usage
Impact of diseases, pests	Soil type and condition	Susceptibility to disease, pests, invasive species
Fractional cover – rangelands	Runoff	Supply and demand for food
Root zone soil moisture	N_2O and trace gases	
Temperature (soil and air for germination)	Crop land cover model	
Species type and distribution	Biofuels parameters	
N_2O and trace gases emissions from crops, feed lots, etc.	Erosion	
Insolation (PAR)	Tillage practice	
Carbon	Ecosystem processes	
Water storage – reservoirs	Water quality and quantity	

4.1.1 Observations that address the information needs

The session attendees recognized that in situ, aerial and spaceborne observations are all applicable to the applications, and that specific observation requirements are dependent, on the scale, temporal requirements and location on the application (i.e., for some locations, in situ observations are impossible and must be replaced by airborne or spaceborne observations. The spectral observation requirements for the applications are listed in Table 2 using the information needs for monitoring to define the spectral ranges.

4.1.2 Requirements for observational frequency

Temporal coverage is dependent on the accuracy requirement. Generally, greater frequency will increase accuracy. Observational frequency cannot be separated from the data latency requirements of the application, i.e., daily acquisitions may be useless if the data (or products derived from the data) are not delivered to the user until three days after acquisition of the observation. Table 3 provides a best approximation of the acquisitional frequency for the applications keyed to "monitoring" requirements in

Table 2.

4.1.3 Traceability to NASA missions over the next decade.

The attendees reviewed the material provided on the characteristics of the Decadal Survey missions, especially the Tier 1 and Tier 2 missions, and commented on the likelihood that data from the missions would meet requirements for agricultural applications. Table 4 summaries the results. The letters in the table relate to the monitoring applications a.-o.

Table 2. Observation needs for agricultural applications

Information Need	**VNIR**	**SWIR**	**TIR**	**Active Microwave**	**Passive Microwave**	**Lidar**
a. Water content of soil and crops	X	X	X	X	X	X
b. Aerial extent and classification	X	X	X	X		X
c. Crop phenology	X	X	X			X
d. Crop residue cover	X	X[1]		X		
e. Crop and natural veg. water use (ET models)	X[4]	X	X			X
f. Disturbance e.g. fires and floods	X	X	X	X	X	X
g. Impact of diseases, pests	X	X	X			
h. Fractional cover – rangelands	X	X				X
i. Root zone soil moisture						
j. Temperature (soil and air for germination			X		X	
k. Species type and distribution	X	X	X	X	X	X
l. N_2O and trace gases emissions from crops, feed lots, etc.		X[2]	X			
m. Insolation (PAR)	X	X				
n. Carbon		X[3]	X[3]			
o. Water storage –				x		

reservoirs						

[1]At least 2 bands near 2.2µm required [2]Mid IR region

[3]Observations between SWIR and TIR [4]Need 4-5 bands on shoulders of water absorption bands starting at 0.52µm

Table 3. Frequency of acquisition for agricultural applications

Information Need	Acquisition Frequency
a. Water content of soil and crops	Daily, twice a week
b. Aerial extent and classification	Monthly, 5 times per year
c. Crop phenology	Weekly
d. Crop residue cover	Seasonal by crop; possible multiple obs.
e. Crop/vegetation water use (ET models)	Daily to weekly
f. Disturbance e.g. fires and floods	Event specific
g. Impact of diseases, pests	Weekly
h. Fractional cover – rangelands	Weekly
i. Root zone soil moisture	Daily
j. Temperature (soil, air and radiant for monitoring germination and ET)	Daily to weekly
k. Species type and distribution	Daily to weekly
l. N_2O and trace gases emissions from crops, feed lots, etc.	Hourly
m. Insolation (PAR)	Daily
n. Carbon	Monthly to annual
o. Water storage – reservoirs	Weekly to monthly

4.1.4 Data distribution and use

The session members strongly endorsed the continuation of the NASA data policy of no charge for data and no restrictions on re-distribution. Also recommended was the distribution of data processing algorithms to increase acquisition of raw data via direct broadcast. Direct broadcast of data is the best way to minimize data latency. However, not all users will have access to direct broadcast. NASA, or the eventual distributor of the data should consult with the user community to understand the data latency issues and requirements for effective use of the data and data products and strive to meet those requirements at the onset of data distribution from future missions.

Table 4. Traceability of Decadal Survey missions to agricultural applications

Decadal Survey Tier	Mission	Applications	Comments
1	CLARREO		Potential impact on climate and weather elements of all the applications.
1	DESDynI	a,b,c,f,h,k	Repeat cycle and ground resolution are a concern
1	SMAP	a,b,d,f,h,j,k	Temporal cycle (latency) does not meet all requirements
1	IceSat II		Repeat cycle is a concern. Good for forest biomass if waveform Lidar is reinstated. Shift in path location may limit utility over land.
2	HyspIRI	a-h; j-m	Direct broadcast capability of real value. Begin working now with simulated data to evaluate impact on applications.
2	ASCENDS	n	Possible CO_2 flux measurements. Orbit not finalized.
2	Geo-CAPE	a-h, k, m	North and South America only. Data over land every 3 hours would be of great value but need ability to adjust gain for overland observations.
2	SWOT	o	Designed for reservoir monitoring requirements.

It was noted that registration of data users by NASA to track how the date are used is reasonable.

NASA data sets are often re-processed periodically to correct errors discovered in the processing algorithms. The session strongly recommended user input on data reprocessing issues, and a commitment by NASA to archive previous all data collections indefinitely to increase the research and applications utility. Data should be archived and distributed on common formats, and data processing algorithms should also be archived to preserve the record. Best data to archive is Level 0, assuming that algorithms are maintained.

The agriculture application elements overlap with all the other application elements identified in the workshop. The primary overlaps are with water resources and weather;

secondary overlaps with air quality, disaster monitoring and mitigation, ecological forecasting and public health.

4.2 Air Quality

For air quality near real time data delivery is very important for many users and needs to be considered by science definition teams. Vertical resolution is desired by end users for understanding variations of air quality through the vertical column. Because of the need to rapid products the users are willing to accept level 1 an quick look data over precise data that have a longer latency for delivery.

4.2.1 Application

Specific aspects of air quality that can be addressed with NASA data include emissions inventories and air quality monitoring and forecasting. NASA data can be sed for constraining emissions inventories, but are also useful for inverse models for constraining sources such as NO_x soil/lightning, mobile sources, and natural sources including dust. The data can be used for both qualitative and quantitative forecasts of air quality. Models for understanding chemistry and chemical mechanisms can be validated with observational data, which can also provide boundary conditions for the models. The data can also be used to assess trends in air quality.

Remotely sensed data can be used to supporting EPA Air Monitoring Networks by filling gaps between monitoring stations. EPA ground based assets can be used to verify the satellite data. The satellite data can be incorporated into planning and state implementation plans for EPA compliance. They can also be used to monitor exceptional events as defined by EPA rules. Exceptional events must be included in planning and development of State Implementation Plans (SIPs).

There are also global applications in air quality such as global treaty monitoring issues global environmental intelligence, and deriving emissions where other data don't exist. Te data can be used to judge the efficacy of policy decisions and for understanding treaty needs, long-range transport of atmospheric pollutants (LRTAP), and hemispheric transportation of atmospheric pollutants (HTAP).

Over the long term the data can be used to understand how changes in air quality drive climate forcing. Does changing climate affect global greenhouse gas emissions? For example, in the Arctic does a changing climate trigger CH_4 tipping point events?

4.2.2 Goals and Objectives

Spaceborne measurements can improve global coverage, provide more frequent observations, increase spatial resolution, and provide data from regions that are otherwise not observed. Sustained measurements will improve climate data records and provide information on long-term changes in air quality. The data can also be assimilated into models as well as be used to test the models. A longer term effort should map NASA's science goals onto the remote sensing goals of other organizations such as EPA, NOAA, USDA, DOE, USGS, DHS, NGA, and local, state, and non-government organizations.

4.2.3 Information Needs

Improved understanding and forecasting of air quality requires understanding of emissions, transport, chemistry, and vertical profiles.

Needed data products:

Data Products	Comments/Notes
O_3, SO_2, AOD, NO_2 column, CO, VOCs (CHOCHO, HCHO), CO_2, NH_3, BC.	AOD: (proxy for PM) BC (using aerosol absorption coefficient or AAOD as a surrogate)
Winds, T, RH, J, PBL(H)	Physical structure of the atmosphere with a focus on the PBL.
AOD vs PBL and RH and PM2.5 on the same time scales. Column vs. surface measurements.	
Vertically resolved chemical measurements.	There is a mismatch between remote sensing capabilities and desired vertical details.
Geospatially resolved GHG surface fluxes on policy relevant scales.	
Biomass emissions (contribution to NEI).	
Surface properties (emissivity, reflectivity, BRDF)	As input to retrievals.
Coupling land property retrievals from satellites to predict biomass state and availability for potential fire emissions.	

Other needs noted are:

- Foreign assets (ESA, JAXA, METOP, Korea, China) as well as more partnerships with other countries. Urge NASA to forge bridges with foreign application providers. This will help promote the open data policy under GEOSS.

- Applications leading to public health uses/warnings. Link to big picture science question. Nitrogen cycle measurements related to ecosystem health (diurnal cycle of air quality), carbon cycle, biogeochemical cycles.

Observations that Address Information Needs

Observations Needed:

- Geostationary observations of air quality related parameters (GEOCAPE)
- Profile measurements from ACE (lidar)
- ASCENDS, OCO(2), NPP(OMPS, VIIRS, CRiS), NPOESS (OMPS, VIIRS), IASI(instrument on METOP), GOME2, TROPOMI. Funding from R&A and APS to work on non-US instruments.
- GHG treaty verification needs some information on the CO_2 columns. OCO(2) if it flies. Some applications are willing to accept lower quality data for some species where no other data exists ("Grey data", e.g. Combination of GOSAT and inverse modeling)
- NASA (and other agency) surface assets like GAW, GALION, AERONET, AIRNOW, MPLNET need to be utilized/retained. Tropospheric science and applications requires a mixture of space-based, aircraft, and ground measurements.

4.2.4 Observation Types

Space, airborne, in situ required for data and data products

- x, t, λ requirements
- Vertical information is important
- Ideally match the resolution of models
- 1 km vertical data would be great
- Discriminate between the boundary layer and the free troposphere
- Don't leave out important λ-channels for cost

Science traceability

Many non-NASA users involved in GEO-CAPE and ACE formulation to date.
Not possible to add to that realistically in the time allotted
Need to see the mission notional STM's and distribute
Need to follow up with the application community participation at Science Definition Team meetings

What are the specific geographic targets?

What is the needed observation frequency and time period for the identified targets?

4.2.5 Traceability to NASA Missions Over the Next Decade

What missions address the goals and objectives of the application?

To missions relevant to the application area wil be launched in the near term – APS on GLORY and OCO-2. There are a number of Decadal Survey missions which could support the air quality applications area. None of the Tier I mission have composition measurements included. In Tier II, GEO-CAPE and ASCENDS are relevant to this area, and GACM, of Tier III. Three missions were identified as having relevance to air quality because of there characterization of key emissions factors such as soil moisture – these missions are SMAP, HyspIRI, and DESDynI. The table below highlights the proposed capability of each mission.

Mission	**Type of Instrumentation**	**Measurements**
GLORY - Aerosol Polarimetry Sensor	• Multiangle, multiwavelength, polarized measurements	• 1. Aerosol optical thickness • Aerosol particle size • Aerosol refractive index, single-scattering albedo, and shape • Cloud optical thickness • Cloud particle size distribution
OCO-2	• spectrometer in o2 A-band and 2 CO2 bands (NIR)	• Precise columns of CO2 mising ratio
ASCENDS	• Multifrequency laser	• High precision measurements of CO2, with some ability to resolve the altitude distribution. • May include a CO measurement.
GEO-CAPE	• UV/Vis imaging spectrometer and CO gas correlation instrument • ocean color measurement • possible IR imaging instrument • uses geostationary orbit	• Near hourly measurements of ozone, NO2, CO, HCHO, CO, and aerosols. • Measurements of SO2 • Possible NH3, HDO, formic acid, methanol • Possible vertical profiles of ozone and other gases if IR is included.
GACM	• UV spectrometer • IR spectrometer • Microwave limb sounder	• CO, NO_2, CH_2O, SO_2, aerosols • Limb-viewing measurements of O_3, N_2O, temperature, water vapor, CO, HNO_3, ClO, and volcanic SO_2 in the upper troposphere and lower stratosphere
SMAP	• L-band radar • L-band radiometer	• the emissions development process could potentially use soil moisture in predictive models (of nitrogen emissions, vegetation state as it

		relates to vegetation emissions). Soil moisture may be useful to relate to fire conditions.
HyspIRI	• Hyperspectral spectrometer	• land surface data could be used to improve surface characterizations for retrievals
DESDynI	• L-band InSAR • Laser altimeter	• vegetation models that are tied to emissions could use vegetation structure

How do these needs trace to the mission capabilities?

In some areas, there is a good match between the needs and the mission capabilities. There is a good match in land surface properties, biomass emissions, and columns of chemical constituents. There is a mismatch in demonstrated remote sensing capability and some needs, such as detailed vertical information, aerosol speciation, and GHG surface flux. Advances in remote sensing, which could result in smaller horizontal footprints, and improvements in vertical sensitivity through multispectral measurements, may bring the needs and capabilities into better alignment in the future.

Capabilities currently included in, or planned for the mission that address application area (see table)

Capabilities that should be considered for the mission to improve relevance of the mission data to application area and impacts of including the additional capabilities

In the discussion for this application area, it was clear that near-real time data products are critical, even if they are fast algorithms with larger errors than the final products. For events that change rapidly in time (fires, air pollution events, accidental releases), it is critical that the data be available in less than 24 hours, preferably within 4 hours.

4.2.6 Data Distribution and Use

Data policy issues

- Open access. Lack of community experience for decadal survey missions to have exposure to products prior to launch.
- Evaluate onboard processing versus ground processing of data.
- Mandatory user registration of data products. Notification to the provider when the data is published/used.

Archival, processing and distribution issue

- Grey data (NRT), Level 2 archived data, machine-usage (WCS calls, etc.) access, metadata services (RSS feeds), searchability, standardization of services (reduce overlap and duplication). Not just direct broadcast.
- ROSES as a vehicle to augment other agency air quality distribution mechanisms (AIRNow – satellite, etc.). ACCESS as another vehicle.

How quickly do the data products need to be disseminated?

- Forecasters and data assimilation need near real time products but this may be secondary to quality data from the project. Ozone and PM are likely candidates for the first assimilation needs so AOD and ozone would be the first species to include in NRT.
- Discriminate between initial product latency (checkout/cal/val) vs routine product latency after checkout (routine quality assurance timeframe).

4.2.7 Potential overlaps with other application areas

Air quality has overlap with weather since the dynamics and weather that move pollution around and set up the situations for air pollution events are closely tied.

4.3 Disasters

The session approached the definition of requirements and appropriate measurements by listing hazards and working through functional requirements for measurements and data products for each hazard. Issues of data latency and in some cases spatial resolution were set aside for later consideration. Core, Tier I, and Tier II missions were reviewed for relevance to the defined hazard requirements. People involved: Bruce A. Davis, Shahid Habib, Michael Goodman, and Friends.

4.3.1 Application

What are the specific aspects of the application being discussed?

More than 20 hazards were identified:

- Hurricanes
- Earthquakes
- Volcanoes / Lahar / Ash Plumes
- Landslides

- Debris Flow
- Tsunami
- Wildfires / Ash
- Floods
- Tornadoes / Severe Storms
- Drought
- Winter Storms / Ice
- Oil Spill
- Harmful Algal Blooms
- Vector Borne Disease
- Pest / Insect Disease Mortality
- Technological
- Power Grid Loss – Space Weather
- Cryospheric Events / Glacier Surges / Rogue Icebergs / Permafrost Melting
- Sea Level Rise / Subsidence / Karst topography (sinkholes)

Hurricanes

Pre

- Continuous wind measurement (sfc and vertical shear), aerosols, surge, microwave remote sensing, latent heat, SST
- genesis and rapid intensification
- 3-day track and intensity
- what if scenarios – interdependencies with infrastructure
- Airborne lidar – barrier reefs

Post- within hours to days

- High resolution (18cm) multi-spectral imagery – damage assessment
- Global (30m-250m) multi-spectral imagery – damage assessment
- Large scale vegetation impact 250-500m
- Airborne lidar – high resolution vegetation
- L- C- X-band radar - change for flood extent and drainage rates

Satellite measurements

- HyspIRI – SST, high res (60m) multi-spectral
- DESDynI – L-band for flood extent and change detection
- GPM – microwave precipitation and radar
- NPP – spectral imagery and atmospheric temperature and moisture profiles: VIIRS – spectral imagery, CRIS/ATMS – temperature and moisture profiles
- SMAP – soil moisture for weather forecast, sfc water mapping, flood mapping
- CLARREO – cal/val for NPP, HyspIRI
- ACE - microphysics

Earthquakes

Pre- Forecast time, location and displacement

- Strain monitoring – lidar and L-, C-, X-band
- Infrastructure maps – multispectral imagery high res
- DEM, Topography
- GPS

Post- within hours with repeat/resurvey, change detection

- Decorrelation – L-, C-, X-band
- Deformation - Lidar
- Infrastructure maps – multispectral imagery high res
- DEM, Topography
- GPS
- Optical imagery – RGB compelling product for decision-makers
- SWIR to see through smoke/fire

Spaceborne obs

- DESDynI – lidar and radar
- LDCM – RGB, SWIR and TIR
- NPP – VIIRS (MODIS-like obs)
- HyspIRI – optical imagery RGB, SWIR and TIR

Volcanoes / Lahar / Ash Plumes

Pre- similar to earthquakes, plus:

- SO2 detection
- SWIR, TIR w/ discrete measurements for high temperature discrimination
- General meteorological conditions: wind speed, direction, particle size for plume modeling (ash, SO2, other gases) ; MISR stereo type measurements

Post-

- SO2 detection
- SWIR, TIR w/ discrete measurements for high temperature discrimination
- General meteorological conditions: wind speed, direction, particle size for plume modeling (ash, SO2, other gases) ; MISR stereo type measurements

Spaceborne obs

- DESDynI – lidar and radar
- LDCM – RGB, SWIR and TIR
- NPP – VIIRS (MODIS-like obs)
- HyspIRI – optical imagery RGB, SWIR and TIR
- GLORY – ash plumes

- ASCEND – atmospheric chemistry (CO_2)
- GEO-CAPE – aerosols (NO_2, SO_2, CO, CH_4)
- ACE – plume height

Landslides – similar to earthquake except smaller scale

Pre-

- Soil characteristics
- DEM
- Precipitation duration and intensity
- Land cover

Post –

- Precipitation (watershed), soils moisture, soil properties, ash depth similar to BAER, elevation, vegetation covers

Spaceborne obs

- DESDynI – lidar and radar
- LDCM – RGB, SWIR and TIR (moisture variations)
- NPP – VIIRS (MODIS-like obs)
- HyspIRI – optical imagery RGB, SWIR and TIR
- GPM – precip
- SMAP – soil moisture

Debris Flows – similar to earthquake except smaller scale and shallow surface

Pre-

- Land cover
- Topography
- Soil moisture, soil
- Precipitation

Post –

- Precipitation (watershed), soils moisture, soil properties, ash depth similar to BAER, elevation, vegetation covers

Spaceborne obs

- DESDynI – lidar and radar
- LDCM – RGB, SWIR and TIR (moisture variations)
- NPP – VIIRS (MODIS-like obs)
- HyspIRI – optical imagery RGB, SWIR and TIR
- GPM – precipitation
- SMAP – soil moisture

Tsunami

Pre –

- Identification of earthquake or underwater and surface landslides
- Coastal DEM at 1m globally
- Bathymetry
- Sea surface elevation
- Bottom (seafloor) pressure gradient – e.g., shoreline depression, open ocean tracking
- Land use / Land cover to predict run-up

Post –

- All weather radar for flood monitoring
- Optical imagery to see run-up extent – high water debris line
- Change detection

Spaceborne obs

- DESDynI – lidar and radar for sfc water extent (inundation)
- LDCM – RGB, SWIR (sfc water extent)
- NPP – VIIRS (MODIS-like obs) – sfc water extent
- HyspIRI – optical imagery RGB, SWIR and TIR
- SMAP – soil moisture for salt water, sfc water extent
- SWOT – sea sfc elevation

Wildfires / Ash

Pre-

- Fuel conditions (VCL measurements), fuel moisture, fuel load and type (i.e., land cover)
- Soil moisture (proxy for fuel moisture)
- Infrastructure
- Topography
- Weather
- Ignition source - Lightning vs. power line vs. man
- Pre-fire imagery to help post-fire characterization (NBR)
- Red flight warning - Temperature, wind

Response-

- TIR, SWIR with high heat discrimination
- Near real time
- Multi-scale products (high res and medium res)
- Tactical (high res 1-meter) vs. strategic (medium 10's – 100m of meters)
- Smoke/aerosols plumes (MODIS)
- Mesoscale / synoptic scale fire induced weather obs and micro-scale winds

- Fire radiative response and flame fronts – any polar orbiting instrument shortwave measurement

Post-

- Severity (vegetation and soils) for BAER / NBR
- Topography
- See debris flows requirements
- Invasive species detection and habitat modeling
- Post-fire vegetation recovery
- High res optical

Spaceborne obs

- DESDynI – lidar and radar for change detection, soils, fuel loading
- LDCM – RGB, SWIR, TIR - land cover, NBR
- NPP – VIIRS (MODIS-like), active fire mapping (although not right for temperature distribution)
- HyspIRI – optical imagery RGB, SWIR and TIR
- SMAP – soil moisture

Flood

Pre

- Precipitation (satellite and in situ)
- DEM, Topography
- LULC
- Water mask – existing hydrology
- Soil properties / characteristics / moisture
- Stream gage – to calibrate
- Meteorology
- Hydraulic – channel bathymetry
- Snow pack and ice dam/flow
- Dams – pool level and release

Response

- Rainfall rates
- High res imagery for levees, dams
- Levee breach and
- Flood extent and depth

Post

- Water quality – hazardous material (L-, C- X-band radar), hyperspectral
- Flood extent and depth
- LULC map

- New bathymetry
- Soil deposition/erosion

Spaceborne Obs

- DESDynI – SAR for sfc water and elevation,
- SMAP - soil moisture, sfc water extent
- HyspIRI – sfc water extent, and pollutants
- LDCM – LULC, sfc water extent
- GPM – precipitation, soil moisture
- NPP – VIIRS, sfc water extent, land cover
- SWOT – sfc water elevation

- Next Steps

- Fill out the assessment of hazards against the missions
- Complete the remaining questions for all hazards
- Develop a matrix of the results to show common or unique application for mission data or products
- SensorWebs – e.g., EO-1

Data assimilation for disaster prediction / response modeling

4.3.2 Use Case – Floods

Use Case Form

	User Community: Emergency Management
Use Case Name	Floods (due to rainfall, not coastal)
Point of Contact	Fritz Policelli, NASA GSFC, Narendra Das, JPL
Goal	Forecasting, detection, monitoring, recovery/mitigation
Summary of the scenario	Triggering event: rainfall, soil moisture; Data needs: soil properties, DEM, land cover Sensors: stream and rain gages, TRMM product – real time; GPM –

	real time; SMAP, GEO sensor giving real time view for the detection, zooming into an area. SWOT gives water elevation All of the above is automatically fetched and fed as inputs into a (geographically customized) flood model by automatic workflows. The outputs of the model are used to: (a) forecast event(s) and also to fill in a spatial and temporal gaps in data. The results of the model are pushed out to subscribing applications users by automated workflows. These results can be in the form of products or alerts. Based on alerts, potentially DESDynI (L band SAR/reflectance) is tasked as part of a flood sensorweb. The radar data is rapidly processed to produce a surface water extent product based on polarization. This product (and/or alerts) is rapidly delivered to subscribing entities by automated workflows. SMAP and HyspIRI also provide surface water extent products and alerts when overflying the regions of interest. These products and alerts are delivered to subscribing entities using automated workflows. GEOCAPE provides flooding images when in field of view, also generating and delivering products and alerts via automated workflows.
Users	Red cross IFRC, USAID - SERVIR, UN, other governments and disaster rel. NWS, FEMA, state emergency operation centers, river forecasting centers – NOAA. Most useful in developing countries due to limited ground measurements (e.g. ground precipitation radar) and infrastructure.
Key systems involved	Onboard software, Direct broadcast, downlink to stations, flood forecast and tracking models and flood products, produced by entities – NASA, UMD, FEMA, DFO. End products: flood forecast, maps of floods, inundation polygons, alerts of projected inundation areas.
Notes, Decadal Survey Traceability	SMAP (L-band SAR), Radiometer; HyspIRI- VSWIR/TIR (ET, land cover, soil moisture, surface water extent), DESDynI (L-band SAR), SWOT (river and reservoir elevation and depth, discharge rate). Timeframe for data delivery to users after event detection (ASAP, < 24 hours). GEOCAPE – multispectral - surface water extent

4.4 Ecological Forecasting

Attendees:

Leslie Armstrong, Fang Chen, Lauren Childs, Steve Kempler, Tom Maiersperger, Bandie Mitchell, Jeff Morisette, John Musinsky, Nikunj Oza, Craig Peterson, John Schnase, Woody Turner, Suresh Vannan, and Robert Wolfe

4.4.1 Specific aspects of the application

- Ecological forecasting seeks to answer questions about the future state of ecosystems
- Ecological forecasting focuses on multiscale, multidimensional problems
- Ecological forecasting has distinctive data management challenges
- Ecological forecasting has distinctive needs for model interoperability
- Ecological forecasting is fundamentally an integrative activity
- Continuum from empirical → process-based models
- Not just downscaling of temp/precip, but derived parameters as well.

4.4.2 Goals and objectives

- Extend ecological measurement in space and time
- Crux of ecoforecasting is extending models forward in time. Spaceborne measurements provide important predictors, but are only for the present and past at this time.
- Spaceborne measurements are a source of derived parameters
- Spaceborne measurements help validate downscaled GCM models/needed data products
- Highly dependent on the particular question being addressed
- Almost always require multiple data types from a variety of sources
- Downscaled climate data are important, but there needs to be some sort of governance or guidance on the optimal (or at least appropriate) data or techniques (we cannot assume stationary).

4.4.3 Needed observations

- Highly dependent on the particular question being addressed
- Hyperspectral and LIDAR particularly important

4.4.4 Observation types

Spaceborne, airborne and in situ observation types are necessary. There could be significant development of ecoforecasting techniques by partnering with NEON's Airborne Observation Platform (hyperspectra and full-wave form lidar at 3m with pan band at 1m). For some applications, the required field data are rare or non-existent. For other applications, there are networks or resources collecting the required in situ data, but there is not a clear way to organize these data in a way to associate with gridded, geospatial data.

4.4.5 Geographic targets

- Terrestrial and aquatic
- Regional and landscape scales
- Increasing need for high resolution

4.4.6 Needed observation frequency and time period for identified targets

- Latency generally not an important driver
- Times series critical, the longer the better
- Back-up or some redundancy is critical if users are going to depend on data

4.4.7 Missions that address the goals and objectives of the application

- HySpIRI, DESDynI particularly important.
- LDCM, GPM, and VIIRS are equally important.
- There are no missions that are irrelevant, but some are application specific.
- Could consider an OSSE-like approach to test contribution or error reduction from potential missions.

4.4.8 Data distribution and use issues

Need for NASA-mediated integration of non-NASA data. NASA has a role helping with marginal efforts needed to tie in situ data to forecast modeling, eg. NACP work with forest service FIA data, GLOBE data, Citizen Science data, etc.

Need for computation/data migration to NASA (vs. data migration from NASA). Perhaps considering the successes of the climate science's Earth System Modeling Framework.

4.4.9 Potential overlaps with other application areas

Climate, air quality, water resources

Note: strong connection with Terrestrial Ecology Science program.

4.5 Public Health

4.5.1 Applications

The Public Health application area focuses on Earth science applications to public health and safety, particularly regarding *infectious disease*, *emergency preparedness and response*, and *environmental health* issues. The application explores issues of toxic and pathogenic exposure, as well as natural and man-made hazards and their effects, for risk characterization/mitigation and improvements to health and safety. Public health researcher are studying respiratory health, infectious diseases, related environmental impacts (e.g. airborne, soil-, vector-, water-borne, and zoonotic diseases, environmental stress factors (these would include heat stress, etc).

4.5.2 Goals and Objectives

What are the goals and objectives that can be met by spaceborne measurements?

Forecasting and analyzing risk environmental factors that affect diseases and environmental health. Further improvements in the application of remote sensing technologies will allow better understanding of disease risk and prediction of disease outbreaks, more rapid detection of environmental changes that affect human health, identification of spatial variability in environmental health risk, targeted interventions to reduce vulnerability to health risks, and enhanced knowledge of human health-environment interactions.

4.5.3 Observations that Address Information Needs

Needed data products

A number of products are needed to study diseases including: surface & skin temperature, wind, humidity, soil moisture, land cover, air quality, precipitation, aerosol concentrations, surface roughness & topography.

Specific data and data products for: research, resource management and policy decisions

Level 1 products for research; Levels 2 & 3 for resource mgmt & policy decisions; gridded data, NDVI, maps, visualizations & tools, model output products, data & products in understandable formats, user-driven products, standardized projections

4.5.4 Needed observations

The data from observations should be scalable from local to regional to global depending upon human health observations being made. Public-health and risk management decision making has benefited from space-based technologies, and can benefit further with improvements in these technologies, through applications that include:

- *Prediction of occurrence of disease or disease outbreaks.* Space-based observations provide spatial and temporal data on environmental changes that affect the conditions related to disease occurrence and can be combined within predictive frameworks to forecast health emergencies.
- *Rapid detection and tracking of events.* Given sufficient temporal or spatial detail, space-based observations can provide data to support rapid detection of environmental changes or pollution events that affect human health.
- *Construction of risk maps.* The spatial extent of space-based observations provides a means to identify spatial variability in risk, potentially improving the scale of environmental observations so that they match the scale of activities in human communities.
- *Targeting interventions.* Activities to reduce the vulnerability of human communities to health risks,including environmental, behavioral, educational, and medical interventions, can be guided, improved, and made more efficient by use of available and proposed space-based observational systems.
- *Enhancing knowledge of human health-environment interactions.* Basic research on the causes of disease is ongoing, and remote sensing of environmental parameters that affect health is crucial for investigations that improve understanding of the spatial and temporal dynamics of health risk.

Observation Types

Space, airborne, in situ observations are required for data and data products.

The ability to integrate data across and between remote sensing platforms is necessary. Another need is data that can be used for calibration and validation of spaceborne data.

Such integration is impossible without continued capture and dissemination of remote sensing data, information that has served as the basis for understanding many larger-scale spatial environmental patterns. These data, combined with in situ epidemiological observations of disease morbidity and mortality, have served as the mainstay of research on environmental factors and disease and recommendations related to human health.

Spatial, temporal, spectral requirements

Geographic targets

Data void areas where there are no in-situ measurements. Areas of disease endemicities (e.g. plague around Santa Fe). Identify areas for environmental factors affecting human health (e.g. heat stress, poor air quality). Area without ground monitoring faculties such as third world countries. Remote sensing data should be enhanced to assist detection and prediction of the places where disease risk is elevated or times when disease outbreaks are likely. Additionally, can such data enhance the rapid detection of events that threaten health. Other specifics are how can risk maps derived from space-based observations be used to enhance public-health efforts directed at education and prevention, what new exchanges can expand interactions between remote sensing system designers and public health analysts that will help identify spatial and temporal risk patterns, and what new understanding derived from remote sensing data can be used to target interventions aimed at reducing the vulnerability of human communities to health risks. Effective incorporation of remote sensing data into public-health and risk management practices requires measurements that are at spatial and temporal resolutions appropriate to the scale of the problems at hand. That often means that data are needed at more finely detailed spatial and temporal resolutions than current technology allows. When rapid response to events is required or continuous monitoring can be used to identify anomalous environmental conditions, fine temporal resolution is required. Accuracy

of measurements can also be improved through aggregation of multiple observations over time; frequent observations can be used for this purpose as well. Experience with risk management applications (e.g., warnings on harmful algal bloom and famine early-warning systems) suggests that fine-spatial-resolution data are required to target forecasts and warnings to specific geographical locations; such targeted warnings have been shown to be more effective than blanket warnings over entire regions

Observation frequency and time period for identified targets

For air quality hourly data aggregated from daily to monthly; for infectious diseases daily to monthly; for heat stress hourly to daily.

4.5.5 Traceability to NASA Missions Over the Next Decade

What missions address the goals and objectives of the application?

In a broad sense all NASA missions carry sensors that can address aspects of health and that can be assimilated into models for tracking and surveillance.

How do these needs trace to the mission capabilities?

Much of the work in public health is in development in context of using satellite data.

Capabilities that should be considered for the mission to improve relevance of the mission data to application area and impacts of including the additional capabilities:

There are no specific health missions, such as a satellite devoted to telemedicine or that provide a suite of sensors for collecting synchronized (coincident) data for tracking specific environmental events. See mission list below.

4.5.6 Data Distribution and Use

Data policy issues

Free and open access

Archival, processing and distribution issues

Data isn't always readily available. There should be an improvement to data discovery; user friendly for end users such as Giovanni; make it easy to integrate with other types of data.

How quickly do the data products need to be disseminated?

Real-time on a continuing basis; onboard processing. Products such as land cover should be produced seasonally at a minimum.

4.5.7 Potential overlaps with other application areas

As noted in the Decadal Survey, various needs for space-based observational data that will help to address human health problems in six areas of application that are cross-cutting across air quality, disasters, ecological resources, agriculture, water resources:

- Ultraviolet radiation and cancer,
- Heat stress and drought,
- Acute toxic pollution releases,
- Air pollution and respiratory/cardiovascular disease,
- Algal blooms and water-borne infectious diseases, and
- Vector-borne and zoonotic disease.

4.5.8 Mission List:

- Aqua:
- MODIS: Vegetative, Land cover, skin temperature
- AMSR-E: Used for precipitation products
- Aura: All instruments: important for air quality
- Calipso: All Lidar: Aerosol products
- CLARREO: Hi-resolution IR (temperature) measurements
- DESDYnl: Biomass changes
- Geo-CAPE: Aerosol products (air quality)
- Glory: Aerosol products (air quality)
- GPM: High–resolution precipitation measurements

- HyspIRI: Skin temperature for heat vulnerability data in near real time
- LDCM: Land cover/Use, skin temperature in high resolution
- NPP: Observations listed for TERRA, Aqua, and Aura (GVF, land cover, skin temperature, precipitation, air quality, etc.)
- SMAP: Soil moisture measurements
- TERRA:
- MOPITT: Pollution
- ASTER: IR (skin temp) and visible (dust) in high resolution
- MODIS: skin temperature, vegetative, land cover

4.5.9 Use Case

Use Case Form

User Community	**Public Health**
Use Case Name	Dust, aerosol, and ozone forecasting for issuing respiratory health alerts and health etiology in the Southwest.
Points of Contact	Stanley Morain (Earth Data Analysis Ctr., Univ. New Mex.); William Sprigg (Dept. of Atmos. Sci., Univ. AZ) Heidi Krapfl (New Mex. Dept. of Health) Maudood Kahn (NASA/ MSFC)
Goal	The goal is to use space-borne sensor measurements in a modeling framework to track events of atmospheric dust, fugitive dust, aerosols, ozone build-up, and associated concentrations that have known health outcomes in the desert Southwest.
Summary of the scenario	The scenario is to forecast environmental factors that have known respiratory health outcomes. This requires having accurate and timely model simulations of dust, aerosol, and ozone contaminations from which health alerts and advisories can be issued (most likely through state and local health authorities, and print and broadcast media). It also means that long-term data records of both environmental conditions and health be maintained for etiological analyses. This complex application requires atmospheric and surface observations from satellites and ground-based systems. A dust entrainment model (DREAM) is nested in NOAA's NCEP/eta model. DREAM assimilates NASA surface observations into NCEP/eta to forecast dust patterns, duration of events, timing, and concentrations. Model outputs are verified and validated statistically using EPA's AIRNow station data. Speciated aerosols and ozone are modeled by assimilating NASA mission data and products into EPA's Community Multiscale Air

	Quality (CMAQ) model. All model outputs are integrated into the New Mexico Department of Health's Environmental Public Health Tracking System (EPHTS) and CDC's EPHTN. Also, prototypical health alerts and summaries are being developed for local health authorities.
Information Needs What are the needed data products, including those for research, resource management, and policy decisions?	For research and modeling, the following data are needed: surface skin temperature, wind speed and direction, atmospheric pressure, humidity, soil moisture, land cover (to estimate aerodynamic surface roughness length), distribution of dust sources, precipitation, aerosol concentrations, ozone and other GHG levels, and digital elevation and topography. For resource management and policy decisions, the following are needed: level 2 & 3 products; gridded data, NDVI, maps, visualizations and tools, model output products, data and products in understandable formats, user-driven products, standardized projections. Modeled PM_{10} and $PM_{2.5}$ dust patterns and concentrations; observations of AOD by species and concentration and O_3 to detect stagnation episodes; aerosol vertical profiles from ground to 1km. Products involved include: MOD09 to obtain 16-day NDVI, MOD12 & its successor MCD12; AMSR-E; SRTM-30.
Observations What are the needed observation types? What are the spatial, temporal, and spectral requirements? What are specific geographic targets? What is the needed observation frequency and time period for the identified targets?	Since parametric observations of atmospheric and land surface parameters vary in their spatial resolution and are gathered from different sources, NASA observations must be resampled for use in the specific target area (see below); (b) NASA observations assimilated into the nested model must NOT adversely impact performance of the NCEP/eta model, but should improve the performance of the dust entrainment simulation; (c) data are needed hourly for atmospheric and dust entrainment and daily to detect aerosol level and stagnation episodes; (d) data must be expressed in measurement units compatible with standard user requirements (e.g. dust in $\mu g/m^3$); and (e) the model domain must be of sufficient size to set initial and boundary conditions for the forecast domain; (f) all data sets must be integrated for cal/val of model outputs The DREAM/eta model domain is 34°N-39°N, 105°W-113°W; The CMAQ model domain is 26°-44°N, 97°-120°W For air quality, hourly data aggregated over daily to monthly time spans and spatially over census tract, zip-codes, SMSA's, counties, or states; free and open access; user-friendly data discovery and retrieval (i.e. one should not need to be a Mission Science Team member to find and use data); long-term data sets; products such as MCD12 should be refreshed every 12-18 months.

Traceability to NASA Missions over the next decade:	In a broad sense many NASA missions carry sensors that observe environmental determinants of health. Many data from these observations can be assimilated into models for tracking and surveillance. The list below indicates what was used, or experimented with, in this “use case”. CALIPSO: Daily aerosol detection; layer heights; model evaluation; aerosol typing; CLARREO: Model improvement through intercalibration of data sets (latency is a problem); DESDynI: (perhaps exposure to volcanic ash) GEO-CAPE: Atmospheric composition; emission inventories; improve AQ models (latency could be a problem) Glory: Improved aerosol characterization (natural & human); improved aerosol quantification and optical thickness LDCM: 15m, 30m, 100m land cover from OLI (GIS ready) NPP: Vertical profile ozone from OMPS; atmos., moisture, pressure profiles from CrIS OCO: No uses identified SMAP: Level-2 active-passive soil moisture @ 9km resolution (latency not good for forecasting dust entrainment) SWOT: No uses identified
Data Distribution and uses Data policy issues Archival, processing and distribution issues How quickly do the data products need to be disseminated?	 Data policy issues have not been a serious factor in this application. We understand that EPA plans to shut down many AIRNow stations in isolated localities and this will diminish cal/val efforts This application retrieves and archives its data sets and processing procedures in FGDC metadata standards. Latency is the biggest issue because the application depends on steady data streams for timely forecasts.

Potential overlaps with other application areas	Climate, air quality, disasters
Users	CDC; NMDOH; UNM-Health Science Center; Albuquerque Public School Nurses; health advocacy groups; potentially NMDOT
Key systems involved	As noted in the list of NASA missions above.
Notes, Decadal Survey Traceability	CLARREO; GEO-CAPE; ACE; GACM; 3-D Winds

4.6 Water Resources

Many research application objectives and needs related to water resources can be met, or partially met, within existing mission descriptions. These application areas include topography/bathymetry, land use/vegetation cover, surface water and groundwater quantity, ice cover, surface water quality, climate/weather, and coastal processes (e.g. altimetry). There is substantial overlap and synergy among water resources research applications with other application areas addressed at the workshop: agriculture, air quality, disasters, ecological forecasting, public health, and weather. There is a broad academic user community for water resources applications, with some potential for developing applications for operational agencies, and therefore a full range of spatial and temporal resolution and of latency is desired depending on the intended use. However, at present almost all of the potential applications are in the science/research domain, not in the world of operational water management agencies and entities.

4.6.1 Applications:

There are many subcategories under the broad heading of water resources, including basic topographic and bathymetric mapping to support modeling activities, identification of land use and land cover (such as for water use estimation), estimation of surface and groundwater quantity parameters, estimation of surface water quality parameters, measuring ice extent, and climate/weather applications. Example parameters within these subcategories are characterized below. Ideally remote sensing observations would provide the capability for ongoing long-term monitoring of many of the desired parameters, rather than a single-mission experimental measurement.

Topographic/bathymetric applications include surface water runoff modeling, defining drainage basin characteristics (areas, aspects, vegetation cover and gradients), and coastal/estuarine mapping. Land use and vegetation cover applications include estimating evapotranspiration and water use of crops or native vegetation, and estimating infiltration (if recently burned, for example).

Surface water quantity applications include estimating flooding/inundation extent, soil moisture, stream flow, snow covered area and snow water equivalent, permafrost depth and distribution, and delineating wetlands. Similarly, ice applications (land, glacial, river, lake, and sea ice) include estimating the timing, distribution, and extent/volume of ice cover. Groundwater quantity applications include estimating relative changes in groundwater levels, monitoring land subsidence as a hazard and as it relates to characterization of an aquifer system, and identifying flow boundaries (faults, facies changes). Surface water quality applications include observation/characterization of physical (e.g. sedimentation and turbidity, temperature), chemical (e.g. salinity, hypoxia), and biological (e.g. algal blooms, invasive aquatic weeds) parameters.

Climate and weather applications (discussed only briefly here as they are being covered in another workgroup) include estimation of atmospheric and near-surface precipitation, and atmospheric moisture distribution and character. Early detection and tracking of atmospheric rivers and improved parameterization of meteorological quantitative precipitation forecast models are of special interest to flood management operational agencies.

4.6.2 Goals and Objectives:

Many research goals and objectives can be met or partially met by spaceborne measurements for the specific aspects of water resources applications, although ancillary data often will be required to fully satisfy some of them. There is presently almost no use of spaceborne measurements by operational water resources agencies, except for a handful of instances where a few large state or federal water agencies are using Landsat-derived products to estimate crop water use in unique locations. The absence of assured long-term continuity of remote sensing observations is a major impediment to development of applications that would be useful in the operational world. Developed countries such as the U.S. have relatively robust instrumental networks for monitoring environmental parameters, and while remote sensing products could – if long-term continuity was assured – help fill in gaps in existing networks, the products are not competitive with instrumental data in terms of precision, accuracy, timeliness, and ease of use.

What are the goals and objectives that can be met by spaceborne measurements?

- Groundwater levels
- What are the goals and objectives that can be met by spaceborne measurements?
- Measure groundwater levels
- Measure deformation of the land surface (INSAR)
- 30-m spatial resolution
- Transfer deformation measurement to groundwater level change
- Remove atmospheric moisture (radar)
- Refine GRACE resolution; Present use is largely by research community; Microgravity; 6-month repeat.

- Ground penetrating radar
- Depth penetration

Landscape (cover/use/shape)

-
- Mature area of measurement; make it amenable to optical, radar, lidar (topo) and thermal. Very broad user community – researchers to operational agencies need to support broad range of derived products.
- Multiple uses include:
- Change detection
- Trend analysis
- Crop/native plant
- ET
- Soil moisture
- Productivity
- Health
- Carbon storage potential (wetlands)

Water Quality

-
- There are many ecosystem uses as shown below. Operational uses include detecting extent and timing of events and require high temporal frequency for operational monitoring. There are some uses in the operational community (Landsat), but more in the research community.
- Optical, radar, thermal
- Lidar
- Using airborne to map chemistry.

Ecosystem uses:

- Temperature
- Spatial distribution for fisheries management
- Groundwater input
- Salinity
- Spatial distribution for fisheries management
- Turbidity
- Spatial distribution for fisheries management

Operational uses:

- Algae
- Detection (extent and timing) of events
- High temporal frequency
- Invasives/aquatic weeds
- Detection (extent and timing) of events
- High temporal frequency

- Surface Water
- There are a broad range of uses, e.g. quantity, location, frozen v. liquid, snowpack, soil moisture. Soil moisture – input to weather and climate models (1 day desired), SMAP levels of spatial and depth resolution and better. Mostly used by research community – for users, need to take look where might be useful to infill point measurements (snowpack most promising).

  Uses:

- Quantity
- Location
- Change
- Impact to water quality
- State (frozen vs liquid)
- Snow pack
- spatial extent weekly
- Snow water equivalent
- Runoff and reservoir management
- Melt timing/duration
- Soil moisture
- Weather/climate models (short and long term), watershed hydrology, wildfire eradication, drought
- 1 day desired latency
- SMAP levels of spatial and depth resolution or better
- Need the data immediately

4.6.3 Information Needs:

The range of information needs associated with water resources goals and objectives is large, and the needs are inherently a function of the intended end uses of a particular product. Generally, a few broad themes can be observed:

- There is significant desire for a higher temporal frequency of Landsat-type products (sans clouds or cloud-corrected) for a wide range of land use/land cover applications, including irrigation monitoring, drought monitoring, and ecosystem monitoring.
- Long-term continuity of Landsat is critical for both the research and operational communities. Maintaining a thermal infrared sensor on future Landsat missions is required for operational agencies to be able to use Landsat products for estimating irrigation water use. Work should begin now on Landsat 9, to ensure no gap of coverage following launch of the LDCM.
- Ensuring long-term sustainability of observations is crucial to development of water resources applications. Unless there is long-term continuity of observations, remote sensing products will have little value for the operational water resources community, and there will no incentive to expend the resources to develop applications.
- Remote sensing data in general, including NASA EOM data, are little used in the applied science and operations sectors of the water resources community,

with the exception of limited Landsat image usage. There is a lack of awareness of remote sensing capabilities in the operational community, as well as a lack of a disciplinary background in the subject area. These factors, combined with the general unavailability of data and products and the paucity of applications development for water-resources problems, translate to the absence of user demands for applications. Substantive usage of remote sensing for water resources management and policy decision-making is not likely in the near-term, a situation especially significant for cross-sectorial applications such as weather forecasting and disaster response, where the most opportunities for product development may exist. Water resources remote sensing information needs are thus dominantly those expressed by the research community, and have in recent years have tended to be driven by climate observations related to USGCRP. (NRC's Decadal Survey itself is an assessment developed by the research community.)

4.6.4 Observations that Address Information Needs:

1. What are the needed observations?

Observation Types

- Space, airborne, in situ required for data and data products. Land use/cover needs ground truthing. Generally, all observation types – space, airborne, and ground-based instrumentation – have a role. Airborne observations are useful for developing proofs of concept for an instrumental application, and for one-time data acquisition for mapping purposes – such as LIDAR mapping of coastlines or structures (e.g. flood control levees). Ground-based measurements — often from data sets collected by federal, state, and local operational water agencies, are essential for ground-truthing (e.g. land use/land cover) and other calibration/validation. The acquisition of ground-based information for calibration/validation of space-based observations offers NASA the opportunity to forge explicit partnerships with operational water resources agencies that would benefit the EOM over the long-term. The workgoup did not identify new observations in addition to those already associated with the planned Tier 1 and Tier 2 missions, except to note that NASA does not have spaceborne SAR assets.

Spatial, temporal, spectral requirements

The specific geographic targets for the missions depend on the application — the U.S. and immediately adjoining areas are an obvious target for many terrestrial water resources applications. Understanding ice processes to better forecast global sea level rise obviously requires coverage of polar areas. Weather and climate applications require global coverage.

The workgroup identified the following temporal or spatial requirements that should be considered for the missions to improve relevance of the mission data:

DESDynI (or GRACEII) – 30m spatial resolution for groundwater applications (e.g. aquifer-system compaction and land subsidence), atmospheric correction on SAR platform, 2 month latency for groundwater applications

ICESATII – need shorter latency than 3 months

SMAP – 1 day soil moisture desired for weather and climate models (and could also be used for groundwater recharge modeling)

SWOT – lower latency

4.6.5 Traceability to NASA Missions Over the Next Decade

Listed below are Tier 1 and Tier 2 missions and their capabilities that could address water resources research needs.

- CLARREO
- Atmospheric moisture to correct INSAR measurements
- Coordinate timing/orbit w/ DESDynl
- SMAP
- Soil moisture including the root zone, but longer latency
- Freeze/thaw ground state (implications for flooding)
- Sea/river/lake ice (onset refreezing extent and ice type)
- Standing water (wetlands, flooding, storm surge)
- Drought monitoring
- Groundwater recharge modeling deep infiltration (below root zone)
- ICESATII
- Surface-water stage (need to turn on at lower latitudes; need lower latency than 3 months)
- Ice thickness: sea and land
- Inputs to hydrologic systems
- Topography
- DESDynI: See DESDynI workshop notes for details
- Hydrological and coastal applications: DESDynI will play a significant role in mapping and monitoring floods, oceans, and coastal regions, including wetland ecosystems, disaster, health, energy, climate, water, weather, agriculture, and biodiversity at local to global scales. The need to map these areas includes detection and monitoring of invasive species, flooding extent, wetland quality, water quantity, wildlife habitat, and carbon storage credit accounting. There have been significant demonstrations of L-band and other wavelength SAR data for a variety applications related to hydrological impacts including those on carbon storage. DESDynI will be a key component for providing radar and Lidar data to understand local and global wetland infrastructure in light of climate change pressures. NOAA has used SAR extensively as an observational tool [14] for monitoring coastal weather effects (i.e., safety of life and property), ecosystem health, fisheries management, and hazards, and for any associated response.

- Subsurface reservoirs: DESDynI will be able to provide unique time-series background data over large areas that can be used to measure aquifer and subsurface formation properties, particularly with respect to ground subsidence, or uplift, from fluid withdrawal, or injection. DESDynI will provide unique observational opportunities for all of the following applications: 1) Determination of geographic distributions of reservoir changes as reflected in surface deformation; 2) Determination of the geologic structure/boundaries/fault slip based on discontinuities in uplift properties; 3) Determination of fluid pressure from uplift and fluid flow property changes; 4) Determination of thermal expansion/contraction properties over entire reservoir areas by linking in situ observations of temperatures with uplift data; 5) Temporal sampling over yearly hydrologic cycles and over long periods of reservoir development; 7) Determination of 3D displacement fields from subsurface fluid movements based on surface-uplift-validated modeling; 8) Contiguous coverage of the surface of the Earth across drainage basins or ecosystems to provide comparative dynamics data; 9) Making longer wavelength observations with a unique ability to look at more areas, in particular in vegetated and cultivated regions; 10) Using multiply repeated observations to improve the ability to extract small deformation signals in areas with large temporal decorrelation because of the improved potential of using PSInSAR. DESDynI-unique opportunities include the ability to have contiguous coverage over land and coastal areas at long wavelengths and to compare areal properties, in particular across vegetated and cultivated regions. DESDynI can uniquely provide geographic distributions of subsurface fluid withdrawals (groundwater mining, geothermal fluid extraction, or oil and gas production) or fluid injections (enhanced oil recovery, natural gas storage, groundwater recharge, geothermal fluid injection or injected carbon dioxide plumes). The areal variations can provide information on geologic structures, fluid flow unit boundaries, and discontinuities in fluid flow units such as faults at the reservoir levels, thermal expansion or contraction responses from fluid injections/production in geothermal areas, or differential responses to fluid pressurization/ depressurization from differential uplift and compaction. The Decadal survey particularly mentions hydrocarbon-resource management and the potential importance of new subsurface applications, such as carbon sequestration as a greenhouse gas mitigation strategy, as areas in which DESDynI may have broad new societal impacts. DESDynI observational repeat intervals will provide baseline understanding of processes before, during and after subsurface system developments through broad areal coverage, repeated temporal sampling, and 3-D displacement model verification. These applications all require an accuracy of a few mm/yr over 10's of km, spatial fidelity pixel size of 30 meters, and weekly to seasonal measurements to deconvolve the influence of shallow anthropogenic signals (e.g., groundwater) from those of deeper processes. An important application of the DESDynI instruments will be monitoring areas in proximity to critical infrastructure such as levees and bridges to detect signatures of imminent catastrophic failure. Often, levee failures are preceded by ground subsidence or uplift in the structure itself or the land adjacent to the structure that indicate increased leakage or decreased footing stability. These technological hazards can be mitigated by DESDynI Applications Workshop Report Subsurface Reservoirs 58 combining long-term observations that determine background ground velocities with frequent measurements to detect more rapid changes

- HYSPIRI
- Temperature, turbidity, sedimentation
- SWOT
- Derived river discharge, surface-water level/stage, reservoir/lake storage change, flooding forecasts, coastal sea-surface height, near coastal/estuarine inundation, saltwater intrusion, bathymetry, tidal variations
- Research users want lower latency
- Caveat—requires SAR processing!
- ACE
- Provides input to improve GCMs that yield precipitation forecasts.
- GEO-CAPE
- Coastal ecosystems, transition zone effects (freshwater/saltwater interface), biotic and abiotic material.
- Airborne pollutants-dry and wet deposition impacts on freshwater sources
- ASCENDS
- Works in concert with OCO mission
- Carbon sinks, wetland functions.
- Carbon sources, drained wetlands, thawing permafrost.

4.6.6 Data Products, Distribution, and Use

There is a major need to make NASA data more accessible, both during the operational life of a mission and afterwards in an archival setting. In the best of all possible worlds, there would be one portal to access all NASA mission data past and present. Long-term archiving arrangements, including with USGS and NOAA, need to be thought out. Data should be open access, especially to non-commercial users (federal, state, local, tribal, international agencies), and free. NASA should work with its partner agencies — USDA in particular — to ensure that NASA-derived products are available in the public domain and are not subject to confidentiality restrictions (e.g. USDA crop acreage imagery).

Quick data access is desirable. NASA should reevaluate the mission tasking/duty cycle if the number of sensors is slowing data distribution. Satellite to satellite transfer and downlink should be enabled.

NASA should recognize that the range of its users' capabilities is broad. Some users will want immediate access to raw unchecked data (level 0/1a), while others will prefer to wait for processed data with metadata and error characterization — both formats should supported. The capability for users to upload coordinates to a NASA portal and to receive a tabulation of all products available for those coordinates should be developed. Data should be available in readily usable file formats (e.g. KMLs, GIS-ready, GeoTiff).

To facilitate improved data continuity and coverage, NASA should investigate data purchases with international and commercial partners and serving that data to users, either directly or via agreements with agencies such as NOAA, USGS, or USDA. Purchased data could fill in gaps in sensors, spatial and temporal coverage (e.g. JAXA ALOS SAR — US doesn't have SAR capability) in existing data sets, or fill in the gap if Landsat 7 fails prior to LDCM launch. To be useful, this information should be consolidated with NASA-generated products into a single data portal.

- NASA's data distribution needs to include outreach to the public and to potential users in operational agencies, to increase the awareness of NASA products and to enable application development.

-

4.6.7 Potential Overlaps with Other Application Areas

The water resources applications described above overlap to some extent with each of the other breakout groups — agriculture, air quality, disasters, ecological forecasting, public health, and weather. Examples of overlap with each of the other principal focus areas include but are not limited to: a) water supply assessments for agriculture; b) contributions to air quality degradation through volatilization of organic carbon from drained wetlands and thawing permafrost; c) hazards and disasters related to flooding; d) hydrologic assessments of aquatic ecosystems; e) endemic and epidemic diseases dependent on water-borne transport or water availability; f) the presence of lake ice and the relation to lake-effect snow.

4.6.8 Use Case and Application Examples

Harmful Algal Blooms

Use Case Form

	User Community:
Use Case Name	Tracking Harmful Algal Bloom (and Hypoxia) in Chesapeake Bay
Point of Contact	Steve Chien/JPL, Fritz Policelli/GSFC
Goal	Track biological coastal and ocean events
Summary of	Heavy rainstorms are tracked using GPM, TRMM

the scenario	Ground precipitation radar and rain gauges also provide data Local meteorology and weather data are also used. Lidar Desdyni for vegetation structure for transport, Land cover from LDCM, NPP (VIIRS) Sediment and nutrients transport models (use DEMs) In situ sensors also measure nutrients in the water. All of the above provide data via automated workflows, a model is automatically run to predict sediment load, physical conditions, and potential for biological activity. Confirm using broad swath space sensor such as MODIS/VIIRS, MERIS, SEAWIFS Using sensorweb automatically task in-situ assets (boats, autonomous underwater vehicles, gliders) to observe event. When overflights occur observe ocean color using HyspIRI VSWIR, GEOCAPE, ACE. Automated workflows generate products and alerts and disseminate to subscribing entities -- Notify local agencies of extent, predictions. Some onboard processing for rapid data delivery. End users of the data are entities responsible for public health as well as land use management (longer term) to decrease future HABs.
Users	Local agencies including relating to water recreation (boating, swimming), fisheries, EPA, NOAA, USGS, USN
Key systems involved	Onboard flight software, direct broadcast for rapid data downlink, nutrient transport models (hydrologic), ocean current, climate, propagation models (physical oceanography), biologic ocean model, atmospheric deposition models (N2 deposition)
Notes, Decadal Survey Traceability	HyspIRI VSWIR ocean color GEOCAPE (hyperspectral) ACE (hyperspectral) NPP(VIIRS) GPM (precipitation) Land Cover LDCM

	Aquarius

APPICATION EXAMPLE – IRRIGATION SCHEDULING

The California Department of Water Resources' (CDWR's) California Irrigation Management Information System (CIMIS) program manages a network of more than 120 automated weather stations to provide data to assist water users in real-time scheduling of crop and landscape irrigation. Initially developed in 1982, CIMIS has more than 6,000 registered users, plus additional secondary users who receive the information from local media outlets and water agencies. CIMIS data are freely available via web access. Available data include calculated or derived values – reference ET, crop coefficients, net radiation, dewpoint temperature – and directly measured values such as solar radiation, temperature, relative humidity, and wind speed. CIMIS weather stations collect data on a minute-by-minute basis and calculate hourly and daily values that are downloaded daily by a central processing system at CDWR headquarters. The data are automatically quality controlled, and reference ET and other parameters are calculated. With these parameters, CIMIS allows users to estimate site-specific and crop-specific water needs for irrigation scheduling purposes, maximizing water use efficiency. Similar irrigation management information systems have been developed in other jurisdictions – The University of Arizona, for example, operates AZMET, which began in 1986 and has 28 weather stations.

There is potential to incorporate data derived from remote sensing into Irrigation scheduling information systems such as CIMIS or AZMET, to help fill in spatial gaps between weather stations. To be useful for this purpose, long-term continuity of appropriate remote sensing data products would need to assured – this would be an operational application, not a research one.

Typical CIMIS Station

APPLICATION EXAMPLE – RUNOFF FORECASTING

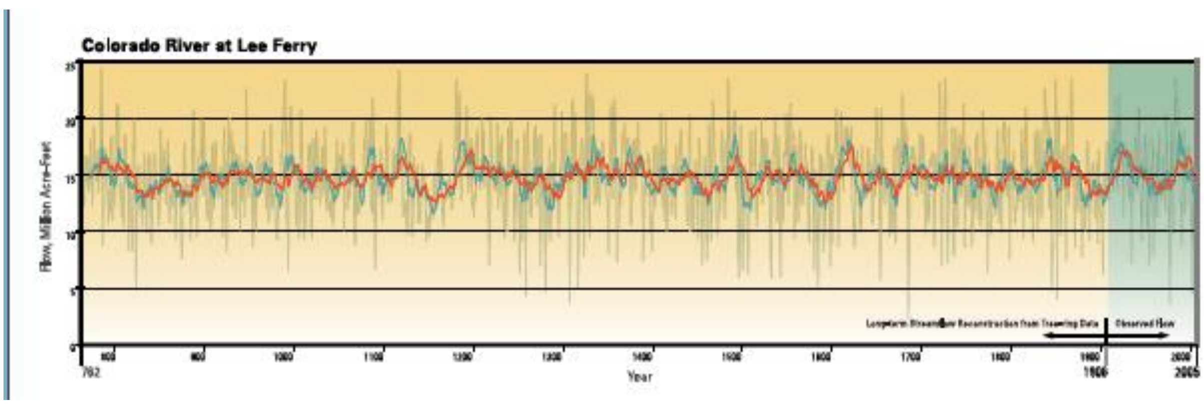
Forecasting snowmelt runoff is an important component of water supply management in much of the Western US. The SNOTEL program of USDA's Natural Resources Conservation Service performs this activity in 11 Western states (about 730 snow pillow sites); in California, CDWR's California Cooperative Snow Surveys Program performs this function (about 300 snow courses and 130 snow pillows). The use of snow surveys to estimate snow water equivalent (SWE) for runoff forecasting dates back more than 100 years to the first surveys performed near Lake Tahoe. In California, more than 50 state, local, federal agencies and private utilities participate in the Cooperative Snow Surveys Program, in which more than three hundred snow courses are manually measured at least monthly to determine SWE. These field measurements are augmented by less accurate automated readings from telemetered snow pillow sites. CDWR uses the monthly snow course data plus real-time data from snow pillows to make monthly forecasts (weekly, for important drainages) of expected runoff throughout the winter/spring season for all significant river basins draining the Sierra Nevada. These forecasts, ultimately based on empirical statistical regression techniques developed over decades of data collection, are used by operators of flood control, water supply, and hydroelectric power projects for project operational decisions and for allocating water and power supplies throughout the year. Remote sensing information could contribute to this process by providing estimates of SWE in areas where there are data gaps in snow courses or snow pillows, especially in the highest elevations of the Sierra. To have value for operational purposes there would need to be an assured source of long-term remote sensing data (beyond the life of a single satellite mission), and the data would need to be mapped onto drainage basin boundaries.

- 
-

Figure 1. Manual measurement of a snow course.

APPLICATION EXAMPLE – THE VALUE OF LONG-TERM RECORDS TO OPERATIONAL AGENCIES

The greatest obstacles to making practical use of remote sensing for water resources operational purposes are the short-term nature of the records and the substantial uncertainty about long-term continuity of information. The standard of practice in water resources management is based on using long-term records – the longest available records – obtained from instrumental measurements. Water resources management is most focused on the need to manage for extremes – floods and droughts – not average conditions, and long-term records are essential to understand the recurrence intervals, magnitudes, and impacts associated with extreme events. Continuous historical records of measured streamflow in the Western US provide at best about 100 years of record – a period too short to quantify, for example, severe drought events known to have occurred prior to the historical record. Water agencies are increasingly turning to tree ring-based paleoclimate reconstructions of streamflow and precipitation to evaluate drought scenarios and develop sensitivity analyses for estimating climate change impacts (see, for example, USBR's 2007 EIR for Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead.) As illustrated below, the Colorado River's reconstructed record shows drought periods far surpassing anything observed in the historical record (University of Arizona data, funding provided by CDWR and USGS).



Long-Term Reconstruction of Colorado River Streamflow

4.7 Weather / Aviation

Operational and research satellites both provide essential capabilities for weather and climate, as well as for real-time hazard detection and warnings. Within in the NASA Applied Science program, there has been an increasing emphasis on applications specifically targeted for aviation weather users.

The potential applications of each observing systems are defined by each missions data latency, update rate, and coverage. Most routine operational applications (e.g. real-time model initialization data sets) are based on the use of US (and international) operational satellites which have larger coverage areas and faster update rates, and which are generally supported as a continuing series of satellites that can provide long-term data continuity. Research satellites, however, can provide unique improvements in our capabilities and allow for the development and testing of new technologies that will eventually transition to our operational satellites.

Polar orbiting research can provide unique contributions for operational support for polar aviation routes.

4.7.1 Application:

Multiple Applications for Earth Observing Missions:

- Climatology, Weather Forecasting, Real-time Hazard Detection & Warning

Different Types of Applications:

- Research (study the phenomena itself, or develop new detection technologies) → Key proving ground for future operational sensors or satellites
- Climatological studies or long-term data acquisition
- Real-time operational support (making use of the unique capabilities of EOM satellites as compared to NOAA's Operational satellites)
- Gap filling to extend coverage or improve capabilities and applications
- Verification and validation studies
- Full spectrum of weather applications – situational awareness, short-term forecasting, data assimilation of atmospheric and cloud properties into NWP
- NWP data assimilation
- Impact of aviation on environment – climate role such as emissions and contrail development
- Highest impact in remote locations such as data void regions such as oceanic/mountainous/polar/oceanic regions (umbrellas all of above categories)

4.7.2 Goals and Objectives:

- Observations to fill gaps in data sparse areas
- Enable early use of future operational satellite instrumentation
- Unique spectral, temporal, phenomenological, and spatial coverage
- High resolution research NASA satellite data can be used to independently develop, assess, and improve NWP, satellite decision support products, future operational GOES-R algorithms
- Synergy with other observations (Example: Convection - FAA CoSPA and Turbulence - GTG), satellite products are not stand alone

4.7.3 Information Needs:

Needed data products:

- Winds/shear
- Cloud properties (icing)
- Volcanic ash/SO_2
- Turbulence

- Lightning
- Thermodynamic state
- Convective overshooting-top/initiation
- Visibility, low clouds/fog

4.7.4 Observations that Address Information Needs

Observation Types:

Space, airborne, in situ measurements required for data and data products to be integrated with other observations and forecast systems

Spatial, temporal, spectral requirements:

- High vertical resolution
- High spectral resolution
- High spatial resolution
- Rapid temporal refresh
- All requirements vary with observation parameter.

4.7.5 *Traceability to NASA Missions Over the Next Decade:*

Unique Capabilities of the Decadal Missions:
Can't compete with geostationary observations for real-time operational support for tropical and mid-latitude areas, but can provide unique contributions from low-earth-orbit missions, including meteorological and space weather support for polar aviation routes.

A unique role for NASA's research satellites:
NASA's research satellites can play a critical, unique role in a wide variety of verification and validation applications. Not the traditional cal-val studies, but rather using the "validated" research satellites to test and evaluate the performance of other systems.

In this application, real-time availability of the EOM observations is not essential, nor is full geographical coverage. And in statistical terms, the independence of these new observations from the research satellites is a "plus."

Listed below are Near-term, Tier 1 and Tier 2 missions and their capabilities that could address Weather/Aviation Weather research needs.

<u>Near-term:</u>
- NPP/NPOESS – broad applications/high relevance – mulitispectral imager and hyperspectral sounding similar to MODIS and AIRS/AMSU capabilities --- KEY MISSION
- GPM – broad applications/high relevance – passive and active precipitation mapping with 3 hour coverage over globe --- KEY MISSION
- LDCM – narrow applications/moderate relevance
- OCO – narrow applications/moderate relevance, surface pressure

Tier 1:

- CLARREO – limited (indirect), primarily used for cross calibration
- SMAP - indirect application through surface forcing in NWP initialization
- DESDyni – limited, possibly derived winds in coastal areas, sea ice (NWP influence)
- ICESAT2 – limited unless provides atmospheric profiles

Tier 2:

- ASCENDS - limited unless atmospheric profiles are derived
- HYSpiri - limited, volcanic ash (in testing)
- SWOT – indirect through model initialization
- GEOCAPE – direct applications to visibility, greater capability if it had thermal IR, aviation impacts on climate
- ACE – broad applications/high relevance, vertical motion from Doppler radar, cloud microphysical and macrophysical properties (enhanced CloudSat/Calipso capabilities) --- KEY MISSION

4.7.6 *Data Distribution and Use:*

Data policy issues

- Publicly and freely available, there should be no obstacles to having access to data.

Archival, processing and distribution issue

- Realtime (direct broadcast)/near-realtime data collection and distribution system to external users with data availability in user appropriate formats, reprocessing and long term archive of all data, product processing from real-time data stream as appropriate.

Timeliness of data products

- Direct broadcast/readout capability for time critical observations strongly endorsed for relevance to weather and aviation decision support

4.7.7 Potential overlaps with other application areas

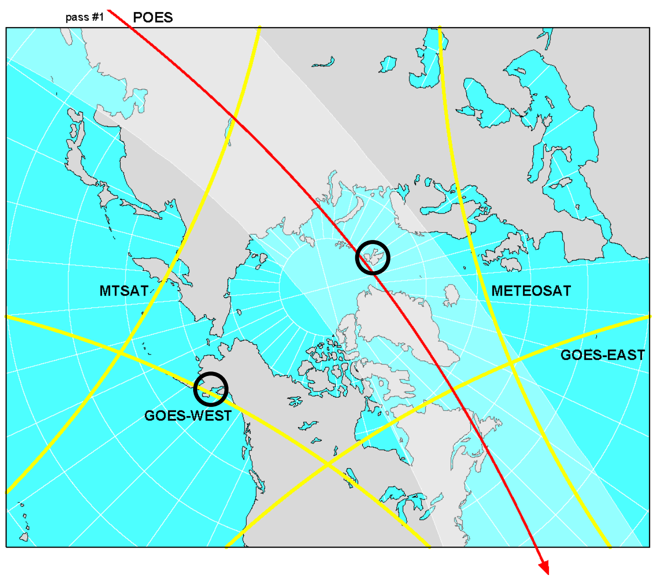
•Water resources, air quality, disasters, and climate.

Application Example: Polar-orbiting Satellites

NASA’s EOM satellites may be able to play a valuable role in supporting aviation operations over the north polar flight routes. These routes are not well covered by conventional observational systems, including geostationary satellites. In this illustration, the yellow lines illustrate the conventional limits to the four (4) main geostationary meteorological satellites (GOES East and West, Meteosat, and MTSAT).

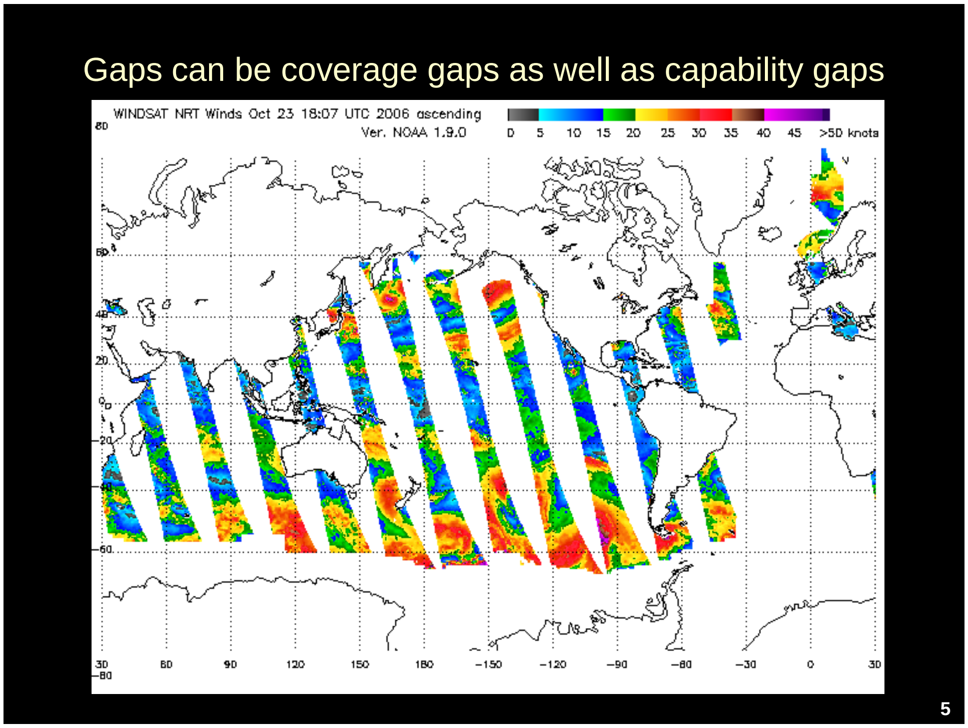
There is current an operational downlink site at Svalbard Island (Norway) and a new NPOESS "safety net" downlink site is being established near Anchorage, Alaska. These two sites (identified by the small black circles) are well located to receive most real-time direct broadcast data from research and operational satellites.

Polar-orbiting Satellites (e.g. EOM)

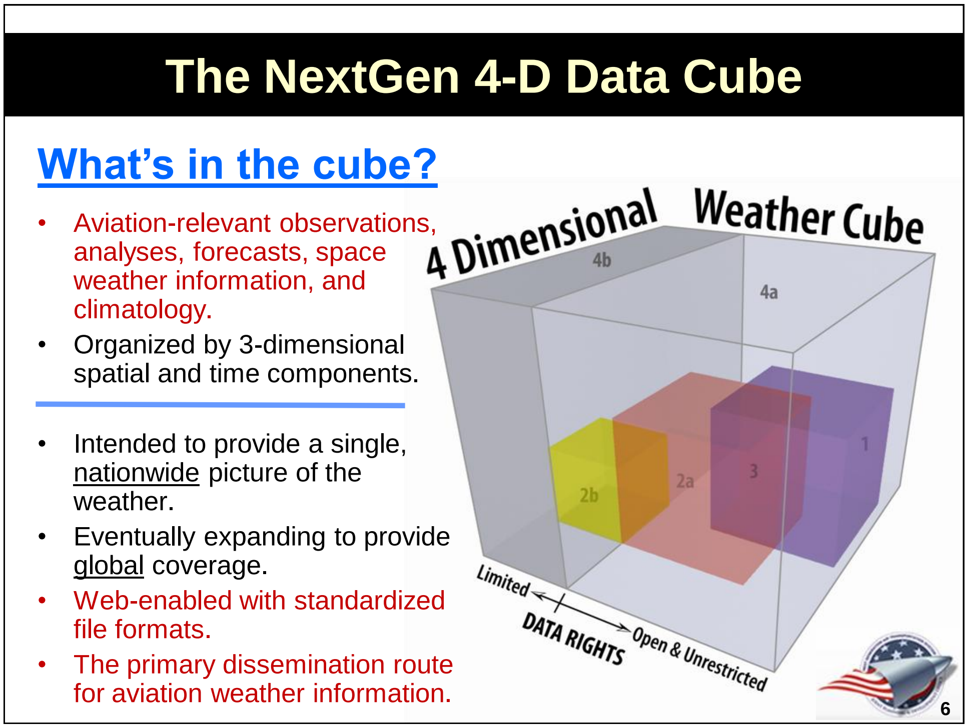


- Critical observations for polar air routes.
- Data latency a major problem.
- The NPOESS "safety net" will be a major advance, rapidly sending the real-time data sets to US operational centers. Could be extended for EOM missions.

3



Formation flying (as in the A-Train configuration) provides a good way to extend the usefulness of both research and operational satellites. In addition to flying along the same orbital track, however, coordinated orbits offset to a slightly different equatorial crossing time can also compliment and fill-in spatial coverage gaps. This can be done by launching additional instruments, or related complimentary instruments to help give true global coverage.



For aviation applications, any new observing system (including data from NASA's research satellites) will very likely need to support the NextGen 4-D Data Cube.

The 4-D Data Cube is being developed for the Next Generation Air Transportation System (NextGen), under the direction of the multi-agency Joint Planning and Development Office (JPDO). Seven agencies are participating in the JPDO: FAA, NASA, Department of Commerce (NOAA), Department of Transportation, Department of Defense, Department of Homeland Security, and the White House's Office of Science and Technology Policy.

Although being specifically developed for aviation applications, the cube (or similar cubes) will also be used for other applications.

The cube is virtual. The cube should include all required (or relevant) weather information required for aviation needs.

5. Cross-cutting Needs

5.1 Data Processing Systems

What improvements in data access are required to meet applications needs? Specifically what is needed?

The objectives of our breakout session were to look at cross-cutting data system needs, including: products, levels, formats, fusion, archiving, access, latency, near real-time data, delivery on demand.

The breakout group was made up of NASA data providers, national operational agencies (USGS,NRL, CDC, etc.), universities, and regional and state application users. The list of 26 attendees and their organization is given in Appendix <*A3.1-1*>. The session was co-chaired by Robert Wolfe and Michael Teague with excellent notes taken by Marge Cole.

The approach the breakout group used to understand the data system cross-cutting needs was to develop a small set of Use Cases and extract the cross-cutting needs from them. The group first brainstormed and came up with the following 16 Use Cases:

- Cyclone location fixing
- Coastal erosion due to extreme storms
- **Climate Change treaty monitoring***
- Air quality trend analysis
- **Snow covered area for runoff forecasting***
- Inflow boundary conditions for ozone distribution
- Near real time land subsidence monitoring for infrastructure protection
- Identify conditions for increased risk for vector borne diseases
- Flash flood forecasting in mountainous regions
- Atmospheric dust forecasting for respiratory health
- Habitat modeling for endangered or invasive species
- Marine navigation for recreational boating and fishing
- **Understanding air pollution caused from extreme fire events***
- Identifying populations at risk because of future climate impacts
- Marine mammal research
- Atmospheric Transport: ozone transport from China to California

The group then identified three cases (*****) to be fully developed that were a represented range of application types. The three use cases chosen (in the order they were discussed) are:

A. *Snow covered area for runoff forecasting*: The goal is to improved runoff and hydrological models and to use these advanced models to help users adapt to climate change. The primary new measurement needed is an estimate of snow cover depth and snow water equivalent over a river basin. Users include: urban and agricultural users, hydroelectric power generators, flood control agencies, national weather service, corps of engineers and major water project operators.

B. *Understanding air pollution caused from extreme fire events*: The goal is when extreme fire events occur near settled areas to be able to issue timely and accurate air quality warnings and enable any needed emergency responses. The primary new measurements needed include: aerosols, atmospheric constituents, biomass and fire intensity (to estimate amount of smoke released), and wind direction. Users include: residents, air quality managers, aviation, emergency responders, security personel and public health officials.

C. *Climate Change treaty monitoring*: The goal is to monitor global climate change treaties by producing global map of greenhouse gas net flux on a monthly or more frequent basis. The primary new and improved measurements include: biomass and biomass change, atmospheric constituents, atmospheric water vapor, fire location and intensity, land cover and land use change. The primary users are national and international agencies concerned with monitoring climate change agreements, as well as, commercial organizations involved in the carbon market.

The details for each of these three Use Cases are in Appendix *<A3.1-2>*.

5.1.1 Needed Data Products and Levels

By looking across the use cases, a number of representative data products and levels were identified. Products include:

1. Level 4 Snow cover depth and snow water equivalent – 10 km spatial resolution
2. Level 2 & 3 Atmospheric constituents by height (aerosols, CO, ozone, NO_2, HCHO, CO_2, CH_4, O_3) – 1 to 10 km spatial resolution
3. Level 3 Biomass and biomass change – 10 km spatial resolution
4. Fire intensity – 1 km or finer spatial resolution
5. Land use land cover – 1 km or finer spatial resolution
6. Digital elevation model – 1 km or finer spatial resolution

In addition several product formats and types of services on the products were identified:

1. Subsetting over the region of interest (e.g. drainage basins)
2. Gridded (Level 3) data
3. GeoTIFF format

5.1.2 Data Fusion

In all three cases, data fusion of data from multiple sensors is needed. Sensors identified in all three cases are: VIIRS, DESDynI and HyspIRI. For Case A, two more sensors were expected to be used: ICESat-II and SMAP. For Cases B and C, six additional sensors were identified: ACE, GEO-CAPE, ASCENDS, OMPS, CRIS and LDCM. In all three cases data fusion process would take place primarily through a modeling effort that brought the individual sensor products together to form a complete picture for the application user. This modeling is expected to be at the regional level (Cases A and B) and at a national level (Case C). Also, the end-user decision makers would not necessarily in the organization performing the modeling. For instance, hydrological modeling is typically performed at the regional (Western States) level and the results provided to the individual state and local decision makers.

5.1.3 Data Access

Based on the use cases, there are four data access areas where improvements are needed: automated delivery, web services, provenance information and accuracy information. For case B in particular, a way to meet the quick response needed for extreme fire events would be to automate the delivery of the products. Rehearsals based on similar past events are needed to be sure that all of the needed data is available in a timely fashion and that all of the linkages between the products, models and decision making processes are ready when the next event begins. Web services were discussed as a way to provide gridding and subsetting over regions of interest. Since both case A and B are for specific areas of interest, providing the capability through web services minimizes the amount of data to be transferred for each application. Provenance and accuracy information are key in all of the cases, but in particular in case C. For climate change verification, traceability of the input data (provenance) and knowledge of the product accuracy is important to the rigorous process needed for policy makers to make credible statements about the current and future climate change. All of these improvements enable the satellite data to be assimilated into models that are the key intermediate processes in all three cases.

Appendix <*A3.1-1*> *Cross-cutting Needs – Data processing Systems Breakout – Participants*

Tom Sohre	USGS	LP DAAC
Michelle Sneed	USGS	CA Water Science Cntr
Marge Cole	NASA/ESTO/SGT	
Francis Lindsay	NASA	ESDIS
Rodgerick Newhouse	Scitor	
Kim Richardson	NRL	Monterey
Robert Ferraro	JPL	
Stan Morain	Univ of New Mexico	EDAC
Ken Keiser	U of Alabama	GHRC DAAC
Alex de Sherbinin	Columbia Univ	CIESIN SEDAC
Philip Callahan	JPL	Radar Processing
Ken Pickering	NASA/GSFC	Atmos Chem
Maggi Glasscoe	JPL	Geophysics Solid Earth
Margaret Srinivasan	JPL	Oceanography Group
Ken Gage	CDC	Div Vector Borne Dis.
Valetine Anantharat	Miss St Univ	
Craig Peterson	NASA SSC	Applied Sci & Tech
Kelvin Brentzel	NASA GSFC	Direct Readout Lab
Greg Osterman	JPL	
Amor Inez	Columbia U	IRI
Jeff Morisette	USGS	
Woody Turner	NASA HQ	
Jeanine Jones	CA Dept of Water Res.	
Ron Blom	NASA JPL	
Robert Wolfe	NASA GSFC	
Michael Teague	NASA GSFC	Sigma Space
Robert Clearfield	NASA Ames	

Appendix <*A3.1-2*> *Cross-cutting Needs – Data processing Systems Breakout – Use Cases*

Use Case A: Snow covered area for runoff forecasting

User Community	• Urban and agricultural users • Hydroelectric power generators • Flood control agencies • National weather service • Corps of engineers • Operators of major water projects
Use Case Name	Snow covered area for runoff forecasting
Point of Contact	Michelle Sneed – USGS, Jeanine Jones – CA DWR
Goal	• Estimate runoff for agricultural and urban use and flood control • Improve operational runoff and hydrological models • Climate change adaptation
Summary of the scenario	• St or Fed operational agency able to access snow cover depth and snow water equivalent • Continuous January through May weekly • Over western states and western Canada • Feed data into current models to estimate runoff for agricultural and urban use and flood control • Improve the models to incorporate new data that reflects climate change impacts
Users	• DWR in CA • USDA in other western states • US Bureau of Reclamation • National weather service river forecast centers
Key systems involved	• Snow cover depth and snow water equivalent at 10 km • Weekly acquisition (less than one week latency) • Geo-referenced • Computed by drainage basin boundary • Accurate digital terrain model, 1 - 10 meters horizontal and 1 meter vertical • Ground truth from river gage
Notes, Decadal Survey Traceability	• Computed by drainage basin boundary is one example of a product ASP could produce in different forms for different customers • VIIRS for snow cover • ICESat-II, DESDynI Lidar for snow depth

	• HyspIRI dust on snow for snow melt potential • SMAP for freeze thaw state

Use Case B: Understanding air pollution caused from extreme fire events

User Community	• Urban residents • Air quality district managers • Aviation • EPA regions; Forest Service • Emergency / local / public health • DHS – infrastructure threats • Intelligence / Dept of State / military (treaty, national security interests)
Use Case Name	Understanding air pollution caused from extreme fire events
Point of Contact	Greg Osterman – JPL; Rod Newhouse – Scitor; Jim Brass - ARC
Goal	• Issue timely and accurate air quality warnings • Trigger emergency system responses • Quantify amount of carbon released • Predict, track and quantify pollution distribution spatially and temporally
Summary of the scenario	• Huge fire occurs near urban area • Flows directly into urban area • Pollution effects, particulate matter and ozone • Predict, track and quantify pollution distribution spatially and temporally • Issue air quality warnings, trigger emergency system responses • Measure population affected • Trigger other assets that help monitor the event
Users	• EPA; NOAA • State, regional, and local air quality management agencies • Intelligence community
Key systems involved	• NOAA and EPA air quality monitoring & forecast systems • Regional & district air quality monitoring & forecast systems • Aerosols AOD, CO column, ozone, NO2, HCHO, CO2 • Biomass • Wind - short forecast • Fire intensity • Topography, land use, land cover • Population density and Infrastructure • Latency requirements, very short term (hours) • 1 – 10 km resolution

Notes, Decadal Survey Traceability	• ACE, GEO-CAPE, ASCENDS, HyspIRI, DESDynI, VIIRS, OMPS, CRIS, OCO • Related uses - controlled burns, treaty monitoring, aftermath of fires-burn scars, pre-fire use related to fuel level, pollution • Additional airborne capabilities

Use Case C: Climate Change treaty monitoring

User Community	• National and international policy makers • Carbon marketplace; Cap & Trade e.g. Chicago Climate Exch., London Climate Exch. (national /international) • EPA
Use Case Name	Climate Change treaty monitoring
Point of Contact	Rod Newhouse - Scitor
Goal	• Combine existing measurements and future data sources to monitor global climate change treaties
Summary of the scenario	• Combine existing measurements and future data sources to monitor global climate change treaties • Produce a high fidelity global greenhouse gas map of net flux over time • Attributing flux to specific countries/ areas • 10 km or less, monthly or better • Provide information to policy makers
Users	• EPA • Intelligence community • NASA climate community (ARC, GSFC, GISS, JPL, etc.) • NOAA • DHS • DOI • USGS • DOE • University partners • International climate community i.e. LSCE
Key systems involved	• NACP (NAFP, FluxNet, etc.) • GHGIS - JPL • REDD – • Biomass, biomass change • CO, CO2, aerosols, CH4/O3, N2O, • Atmospheric water distribution, water column • Fires • Land use, utilization • NOAA Carbon Tracker

Notes, Decadal Survey Traceability	• DESDynI, OCO, LDCM, ACE, GEO-CAPE, ASCENDS, HyspIRI, VIIRS, CRIS, OMPS,

5.2 Spatio-temporal Information and Services

Contacts: Karl Benedict - kbene@edac.unm.edu, Siri Jodha - sjsk@nsidc.org

5.2.1 Data Geo-referencing and Co-Registration

A primary requirement of the applications community is accurate georeferencing of data products. This is essential for combining and comparing repeat acquisitions by the same or different sensors. Studies show large errors in change detection and classification can results from small co-registration or geo-registration errors (Townshend, et al., 1992). Georegistration of data from other sensors, such as satellite-based laser altimetry is also essential. Additionally, precise repeat ground tracks are important for minimizing co-registration errors.

Another important issue affecting usability of raster data is the dilution of horizontal accuracy and information content through resampling and reprojection. Users often require data in a projection other than the one used to produce Level 3 products. But operational agencies don't necessarily wish to invest the effort to do reprojection, orthorectification, and coregistration themselves. Other users want access to lower level data so they can perform reprojection or fusion with other datasets. NASA should consider offering reprojection as a service to be used only as requested. Metadata accompanying or embedded in the data must convey accurately what was processing or transformations the data have gone through.

One solution for reducing co-registration errors is sensor oversampling. This allows optimal matching of scene pixels to the desired projection grid.

The group felt that it was important to embed georeferencing and projection information in metadata embedded in data itself, such as with GeoTIFF tags. NASA should encourage industry to adopt standard models for reading and using such georeferencing metadata.

5.2.2 Data Access and Delivery Services

Data and information access and delivery for application developers and end users requires flexibility in several dimensions:

- Compositing models (temporal and spatial)
- Transformations (subsetting, reprojection)
- Discovery
- Delivery methods (standards-based services, APIs, FTP)

Different applications benefit from data products that are made up of multiple source data files in different ways. For example, agricultural modeling and prediction applications benefit from the availability of 10-day rolling composite products derived from MODIS data, while land use/land cover dynamics applications benefit from standard 16-day composites across sensors that facilitate data fusion and comparison over common temporal spans. Similarly, the development of some remote sensing data and information applications would be streamlined through the availability of user-specified regional composites and/or subsets as an alternative to fixed tiling schemes used for distribution of RS data products. These observations contribute to the several recommendations regarding the development and support for flexible data and information delivery systems for the next generation of Remote Sensing platforms and sensors.

End user and application needs vary continuously and in order to best meet those needs, a flexible data delivery system that publishes machine-accessible services that support user-specified compositing, subsetting (temporal and spatial), coordinate reference system, and data format options will be the optimal solution for meeting evolving application needs without requiring continuous development of new "standard" products that meet new application requirements. As an example, a service that can satisfy an incoming data request for soil moisture data covering a specified region (which may encompass several tiles of internally stored Level 1a data), composited over a specified 10-day period, and delivered as a GeoTIFF in an EPSG:4326 coordinate reference system would significantly streamline the development of an agricultural forecasting application.

To further streamline application development and the delivery of custom data products to end users, the development of a user preference/profile system would be useful. In this context, users (or systems) would be able to authenticate to the data and information system and services, and through that process retrieve stored preferences for default product generation values such as coordinate reference system, region of interest, data delivery format, interpolation algorithm, etc. The value of this authentication-based preference system would be further enhanced and made more valuable by the ability to use a single-sign on system across data centers to allow for consistent access and information retrieval regardless of the specific data center being used.

Single sign on is one example of how a degree of consistency between missions and data centers would benefit application developers and end users. Another area where consistency between missions and centers would streamline application of Earth Mission data is in discovery of data products that is enabled by semantically-enabled faceted search tools that are based upon a common set of ontologies. Through the use of a common semantic framework, federated search across data centers and mission products would be greatly enhanced, both in terms of the relevance of search results, and the "one-stop-shop" model for discovery of applicable data and information products.

A third area of productive consistency across data centers would be through the adoption of a common set of data access models that are uniform across missions. These access models would necessarily be diverse, as end user and application needs for delivery also vary considerably by use case. The following access models were identified as forming a core set of capabilities that it would be useful to enable across data centers and missions:

Open Geospatial Consortium (OGC) visualization and data delivery service standards. OGC Web Map Services (WMS), Web Feature Services (WFS), and Web Coverage Services (WSC) provide the capability to deliver data visualization (WMS) and data (WFS and WCS) into a wide variety of client applications that support these standards.

Included in these applications are Desktop GIS applications, Virtual Earth applications, and a number of internet mapping and analysis tools.

A standardized data access application program interface (API) across centers and missions

The OGC standards meet some data access needs, but don't necessarily provide the degree of flexibility in data access and delivery that would be required by some applications - particularly in terms of flexible data extraction from multi-dimensional data collections. OpenDAP was suggested as a potential model/foundation to look at for such a general-purpose data access and extraction API.

Continued use of file transfer protocol (FTP) data pools for simple download

The availability of simple browsable FTP data collections was seen as a third data access model that would continue as a useful approach, particularly for users with low bandwidth connections or needs to pull data using a standard protocol.

Information delivery to mobile devices

Mobile devices are increasing in their prominence as decision support and information delivery platforms. These devices are typically lower (relative to desktop clients) bandwidth and smaller screen-size systems that benefit from specialized services to support their applications. While no specific recommendations were made regarding mobile devices, it was felt that it is important to keep in mind the delivery of information to this particular class of devices as Earth Science information systems are developed to support future applications.

Specialized data and information delivery to other Agencies

While data exchange between agencies might be accomplished through the above OGC, API-based, and FTP models described above, it is likely that other, specific data exchange protocols will need to be developed to streamline the delivery of NASA Earth Science data and information in support of applications under development and in support of other Agency activities.

Finally, the issue of data provenance was raised as an important component in delivering information about the source data used in the generation of derived data and information products. The recommendation was to develop of a common framework within which provenance information may be incrementally built as data and derived products move through processes and workflows. This would enable the viewing and assessment of a given product through examination of the stream of products and processes that had been executed in the generation of that data or information product. NASA, through its science teams or data centers, should also consider formally publishing datasets, so that they could be assigned persistent identifiers that would assist in referencing and documenting these assets.

5.2.3 Visualization Tools

Visualization of spatio-temporal data plays a critical role in the rendering of data into actionable information for Earth Science applications. A wide variety of visualization tools already exist for the multi-dimensional data that are typically used in application contexts, but in many cases these basic capabilities can benefit from further evolution, both in terms of ease of use and ability to support common Earth science data formats and models. Several key capabilities were identified as key in the use of spatio-temporal data in application contexts.

First, while data visualization is sufficient in some application contexts, a need for the ability to drill-down into underlying data values through visualization tools was identified as a key capability in some application contexts. The ability to explore large data collections (potentially measured in GB or TB) through rapid visualization, without having to transfer all those data to the client application, is further enhanced if, after the user identifies phenomena or subsets of data that are of interest, is able to transfer just that data to their client application.

Earth Science data, including the products that will be generated as part of the Decadal Missions, nearly always have a temporal dimension as part of their data model. Visualization and animation of data with a temporal dimension is supported by a variety of applications (for example Google Earth and World Wind), and is also enabled through the OGC WMS standard, but still can benefit from significant new development in terms of ease of use and performance. The long time depth of NASA's data archive, in combination with new data acquisitions that are in progress and planned, contributes to the key role that NASA can play in contributing to the further development of the next generation of visualization tools for temporal data.

This potential leadership role for NASA extends further into the realm of volumetric visualization in which 5-dimensional data (spatial, temporal, and spectral components) may be viewed and extracted. As a producer of 5D data (both from the DS platforms and from Models) , NASA is well positioned to increase the value of its data and information products in applications through support for the continued development of 5D visualization tools and applications, including support for immersive visualization platforms such as multi-walled virtual reality caves.

At the other end of the spectrum from data intensive 5D visualization systems, are online analysis and data exploration tools that may be run over low-bandwidth network connections. Support for these capabilities may be accomplished through data extraction services such as those that were described in the previous section, or through higher-level data analysis services that deliver summary plots or statistics to requesting systems (i.e. web applications).

Finally, continued support and consideration of existing client applications such as desktop GIS, Virtual Earth, and web-based visualization platforms should remain an important area of work for NASA. To a large extent this support may be enabled through the deployment of standards-based data and visualization services (i.e. OGC, OpenDAP), upon which standards-based visualization products (e.g. KML), and non-standard (but broadly used) "wrapper" files such as ArcGIS MXD files may be based.

5.2.4 Geospatial Standards

Metadata on product quality is essential for proper application and interpretation of data. However, the complexity and encoding of quality information (i.e. data quality flags) can be impediment to proper usage. Many application developers do not have the expertise to interpret, or to easily decode, quality information in some NASA EOM products. The recommendations coming from the group included:

- Make it easier to employ quality information in searching for data
- Synthesize quality metadata into simpler, uniform quality measures
- Strive for consistency across missions in how quality information is represented and encoded in the products

Interoperability of EOM data is greatly enhanced by having a common data format. But community needs and sensor product characteristics may favor different formats in different circumstance. NASA should consider having a single data format across all missions, such as NetCDF, or determine a short list of formats that data distribution points would be encouraged to provide data in to serve different user communities.

Even more important than data encoding is the adoption of common conventions for variable names, units, etc., as are specified in the CF Conventions (http://cf-pcmdi.llnl.gov/), which could be employed independent of data format.

A concern was expressed that the convention used for expressing horizontal accuracy in many NASA EOM products is not what is common in initiatives such as the National Spatial Data Infrastructure (RMSE vs CE90%). It is recommended that NASA adopt common standards in the representation and characterization of spatial accuracy.

A common metadata content standard is important for consistent and accurate data discovery, access, processing and interpretation across heterogeneous data systems. We recommend that NASA adopt the ISO 19115 and related metadata standard and consider developing a profile for all Decadal Survey missions. This profile would include required and optional elements, controlled vocabularies ("Code Lists"), and uniform methods for specifying measurement quantities, georeferencing, quality indicators, access constraints, and the like.

NASA Earth Science Data Systems Working Group has established a Standards Process Group (SPG) that evaluates and recommends standards for NASA missions. NASA should actively encourage participation in the SPG by the applications community.

Use Cases (use in sidebars) http://tinyurl.com/geospatialusecases

- Cal-Val of Ground Level Atmospheric Particulate Modeling
    - Fuse ground observation data (e.g. EPA AirNOW) and RS data to validate and calibrate atmospheric forecast models of ground level particulates
- FEWS Net

    - Provide actionable, policy relevent information to USAID. Informs targeted use of limited resources.
- Aircraft Synthetic Vision Systems
    - Aviation Safety – allow civil aircraft to safely fly & land under any visibility conditions
- National Agricultural Statistics Service
    - Improve agricultural forecasting, monitoring, measurement
- California Water Supply
    - Improve forecasting and management of water resources
- TOPS EcoCast
    - Nowcasts of ecosystem conditions

5.3 Data Delivery Systems

Data delivery systems encompass the array of capabilities and associated technologies for the capture, transmission and delivery of data acquired by NASA satellites. These systems provide the essential linkages between observation capabilities and end users; encompassing ground receiving stations, networks, direct readouts stations, processing algorithms and science processing and distribution facilities. In the context of supporting applications using NASA's research measurements, data delivery systems are the "last mile" or the final leg in delivering data to application users for societal benefit and improved research capabilities. The composition and configuration of these data delivery systems have traditionally been defined by the needs of Earth science researchers. Transitioning to support application requirements requires a reevaluation of current capabilities to formulate future requirements. Application users often need data much sooner than routine science processing allows, usually within 3 hours, and are willing to trade science product quality for timely access. To better understand how applications will influence future data delivery systems an evaluation of application latency requirements and support for data processing algorithms along with other issues were evaluated during the Data Delivery Systems Breakout session.

A number of methods were used to garner information from current application users. Structured and open discussions were focused on teasing out preliminary requirements for data latency, the role of direct broadcast services, utility and shortcomings of near real-time data delivery systems and algorithms and tools. Representative use cases were developed to describe prototype applications that are currently using near real-time data products from existing systems and the group was surveyed to understand the "sensitivity" of applications to data latency and synoptic spatial coverage. Each of the sections below highlights information garnered from these discussions.

5.3.1 Data Latency

In the applications for societal benefit environment, latency can be defined as the duration of time between satellite acquisition and data product availability to end users including transmission from satellite to ground station, cumulative network transfers and data processing to the required product level. For many applications, lower latency is preferable for hazard and severe weather prediction and response while processes such as drought require science quality measurements.

1. Latency
    a. Some things may be too expensive for a research capability to implement (i.e. aviation volcano ash plume warning).
    b. Application Data Latency Classes
        i. < 30 minutes
            1. $ High cost – implies a ground receiving system with processing capabilities, or a user located near one ($150K for a receiving system)
        ii. < 3 hours
            1. $ Doable – relatively low cost for users who can access data products from a nearby ground station and/or possess an adequate network bandwidth
        iii. < 24 hours
            1. $ Most products achieve this latency for science quality and there is minimal cost impact
2. Manage expectations
    a. Polar orbiting
        i. No lingering capabilities
    b. Product quality may be lower than science quality products due to timely availability of ancillary data sets
    c. Duty Cycle
        i. Instrument – selective spectral data availability due to large on-board data volume. The user community has not come to terms with this yet, and is concerned of their spectral data being cut - impacting their data needs.
        ii. Transmitters – ensure adequate power to close the link with most existing and up-and-coming ground systems
        iii. TDRSS
3. The latency requirements have been found to be significantly varied but generally fall under the pre-defined latency categories of real-time (less than 30 min), near-real-time (less than 3 hours) and delayed (greater than 3 hours). In analyzing the

level of importance/priority, true latency, quantity and correlation with the application, yielded the necessity of creating a matrix which could readily bring out this information and as well as allow for cross reference for relevance with NASA applications' program.

An application and traceability matrix was created (see below) and an attempt was made to capture as much information as was available by those present. It is expected that this matrix will become a living document as more users are engaged. This matrix is also designed to support the Use Cases which provides significant detail of the application.

The matrix information was categorized into three preliminary types of users:

a. Government
    i. Weather/forecast modeling
    ii. Fire management
    iii. Disaster/Hazard response
b. Commercial
c. NGOs'

				Application Data Latency and Traceability Matrix					
Organization	**POC**	**Application**	**Ideal Latency**	**Maximum Latency**	**Data Access Method**	**Spatial coverage**	**Spaceborne Instrument**	**Instrument Data Type**	**GEOSS Connection**
CDC		Public Health	12 hours	12 hours	Direct Readout & Internet & DAACs, LANCE	Regional			
FAA		Volcano plum avoidance	< 5 minutes	5 minutes					
NWS (NOAA)		Now and Forecast	< 1 hour	< 3 hours					
NWS (NOAA)		Numerical weather prediction	< 3 hours	< 3 hours					
USDA Forest Service		Fire supression, management	< 15 minutes	< 3 hours	Direct Readout	Regional	MODIS, ASTER, VIIRS	Spectral, Radar, Lidar	
USDA Forest Service		NRT Disturbence Mapping (8-day composite)	1 day	1 Day					
USAID		FEWSNet	1 day	??					
ARMY - CRREL		Civil and tactical troop deployment (Soil Moisture)	<3 hours						
FEMA		Earthquakes Floods, Hurricanes	<3 hours	??	Direct readout, Data Uplink	Regional			
EPA									
USDA	Glen Bethel								
NIC	Bill Pichel								
AF-OFFET weather center									
NRL - Monterrey									
DOI - USGS									
Dept of Homeland Security									
Coast Guard									
Academia									
NGOs	John Musinsky / Woody Turner	Prevention/enforcement/rapid response to illegal logging, deforestation, fires, illegal fishing, pollution	4-hours - 1 da	1 month	Internet/DAAC access of raw data with RT notifications of data availability; FTP push of pre-analyzed data (i.e., data product); possible direct broadcast in remote regions	Global & regional (e.g., high priority regions in tropics)	Current: MODIS, TRMM, ASTER Future: DESDynI, HyspIRI, GEO-CAPE	Mulispectral, hyperspectral, RADAR, LIDAR	
Commercial Sector									

5.3.2 Direct Broadcast Services

What are the needs for direct broadcast? What are the needed downlink improvements to meet applications needs?

1. Is key for data service providers (NWS, USDAFS, FEMA, EPA, Ch 4 & 5 Weather, etc). This is just for the U.S. International needs are significantly higher.
    a. All "users" present represented a service organization (data product provider) where they used real-time data for the generation of a product which is subsequently provided to end-users for action.
2. Latency of prime importance and/or network connectivity inadequate to support NRT data.
    a. Fill the gap where latency is the most important requirement.

5.3.3 Near Real-time Data Delivery

How would near real-time data delivery on demand better address applications needs?

1. Accessibility
    a. Bandwidth varies in by area (country, remoteness, etc).
    b. Product level and suitability need to be appropriate for application
2. Bandwidth optimization – request only what is needed
3. The user community's definition of on-demand includes the ability to geographically sectorize and spectrally select instrument data. This is also expected of the L2 products although in this case on-demand also includes the ability to request specific data products not normally generated on a scheduled basis. Message to NASA is that expectations need to be tempered and confined; since requirements for this type of on-demand data can very quickly get out of hand.
    a. Includes availability and requests for corresponding ancillary data

5.3.4 Science Processing Algorithm Services

What is the need for availability of instrument-specific science processing algorithms (Level-0 though Level-2 code) along with corresponding processing tools?

1. Functionality (aka Tools)
    a. Need tools to extract only the data needed in the format and with the parameters that are important.

    b. Would like data mining capabilities to provide context to anomalies detected in the forward processing stream.

2. Data quality

    a. KJM Opinion – Validation and documentation of NRT products by science teams is needed to ensure that user feedback and evolving user needs are translated to appropriate product modifications'.

    b. Needs to be consistent, therefore a succession plan from one algorithm to the next needs to be well advertised

    c. Parallel processing of different algorithm versions to maintain consistency

3. Expand data utility

    a. Based on the limited user attendance it was clear that most of the applications are based on NASA's science algorithms. Further, these algorithms and subsequent products are only a first step in their processing chain towards the generation of a user-specific product. Therefore, availability of core algorithms provide the end user with a reference and building blocks to more effectively and efficiently generate their specific product

        i. It also enables instant "buy-in"

5.3.5 Cross-cutting needs use cases

Use Case Name	Point(s) of Contact	Goal	Summary of the Scenario	Users (actors)	Key Systems Involved
FEWS NET	Molly E Brown, NASA. James Verdin, USGS and Gary Eilerts, USAID	The Famine Early Warning Systems Network (FEWS NET) is a USAID-funded activity that collaborates with international, regional and national partners to provide timely and rigorous early warning and vulnerability information on emerging and evolving food security issues. FEWS NET professionals in the Africa, Central America, Haiti, Afghanistan and the United States monitor and analyze relevant data and information in terms of its impacts on livelihoods and markets to identify potential threats to food security.		Actors who use FEWS NET products include - Agriculture and Health experts in country - Nutrition and food security specialists working directly with FEWS NET, who use the RS data in their efforts to create maps of regions that are food insecure - Physical scientists who work on agricultural monitoring	The USGS, for FEWS NET, uses the NASA 'bent pipe' to get real time MODIS level 1 data as an input to the eMODIS product. It has its own web portals where it serves up anomaly maps of rainfall, yield, rangeland productivity, vegetation index anomalies, and a wide variety of climatic analysis product for use by its analysts. These websites are http://earlywarning.usgs.gov http://www.cpc.ncep.noaa.gov/products/fews/briefing.html http://zippy.geog.ucsb.edu:8080/EWX/ This last one was created expressly to provide NASA data in a format and with tools that allow for interactive data exploration while still being 'light' enough for serving to Africa and Central America with very slow connections.
Line-of-sight	Kevin Murphy	Provide over the horizon capabilities for direct readout stations to improve regional weather forecasting.	Data collected from polar orbiting satellites may improve forecasting capabilities of regional weather forecasting models. In some instances, data beyond the horizon could be useful for refining forecasts, especially when the satellite overpass is just beyond the horizon.	Regional weather forecasts, early warning systems	satellite platform, direct read-out station, software and models

Use Case Name	Point(s) of Contact	Goal	Summary of the Scenario	Users (actors)	Key Systems Involved	Notes
Cal-Val of Ground Level Atmospheric Particulate Modeling	Karl Benedict (provided by, kbene@edac.unm.edu), Maudood Kahn (Maudood.N.Khan@nasa.gov), William Sprigg (wsprigg@email.arizona.edu), Stan Morain (smorain@edac.unm.edu)	Fuse ground observation data (e.g. EPA AirNOW) and RS data to validate and calibrate atmospheric forecast models of ground level particulates for use in epidemiological research and public health applications.	In order to perform ongoing model validation and calibration modelers and their application development partners need access to long term records of remote sensing and ground observation data. These data are at vastly different spatial scales and characteristics (i.e. ranging from point observations of local areas by ground instruments, to synoptic RS total-column observations, to curtains generated by sounding instruments), and temporal resolutions (i.e. hourly, multi-hourly, to multi-weekly); and are used in the statistical characterization of model performance for use in research and applied scenarios. These scenarios include epidemiological analysis of relationships between particulate concentrations and exacerbation of respiratory illnesses, notification of sensitive populations to potentially dangerous particulate concentrations, and planning for potential public health effects of various climate change scenarios.	Atmospheric modelers, application developers, end users of applications and information products (i.e. epidemiologists, public health officials, health policy makers)	Remote sensing and ground observation systems and networks. NASA and EPA Data management systems and related data services. Data and information delivery services and interfaces.	This use case sits between the data management and delivery systems provided by Federal agencies (though state and local Govt. agencies might be involved as well as data sources), and the application user communities represented by public health officials, epidemiological researchers, and policy makers.
FEWS	Molly Brown, James Verdin (USGS), Gary Eilerts (USAID)	Provide actionable, policy relevent information to USAID. Informs targeted use of limited resources.		Data providers (NASA, NOAA, USGS, Chemonics, DOD, USDA), Analysts, Decision-makers (USAID, Humanitarian Aid Orgs, National Govts.)	VIS/NIR Daily, SWIR/IR, TRMM, Vertical Profiles, SST, Winds (Upper/lower level), regional land cover (30m). LIS. Collaborative analysis via Web Meeting Software. Web portal(s) (http://earlywarning.usgs.gov/, http://www.fews.net/Pages/default.aspx, http://zippy.geog.ucsb.edu:8080/EWX/index.html)	

Use Case Name	Point(s) of Contact	Goal	Summary of the Scenario	Users (actors)	Key Systems Involved	Notes
Aircraft Synthetic Vision Systems	Rob Kudlinski, Steve Young, John Murray	Aviation Safety – To allow civil aircraft to safely fly & land under any visibility conditions.	Use space and airborne LIDAR and imaging systems (i.e. SRTM, Airborne LIDAR) to develop, maintain, and visualize geospatial databases with layered terrain, obstacle and airport maps with sufficient accuracy required for each of the 3 phases of flight against with no out the window visibility. Integrity of database was co-registered and verified in real-time using onboard FLIR, Weather radar, and GPS systems. Next steps are to have sufficient geospatial accuracy to support world-wide operations and to incorporate other real-time data (i.e. weather, turbulence, in-flight/runway traffic)	Flight data providers (i.e. Jeppesen), Aircraft/deck equipment developers (i.e. Boeing, Honeywell, FAA), Aircraft owners (i.e. Delta, GA), End users (ATC, flight crew and passengers)	SRTM, Airborne LIDAR, Imaging satellites, weather satellites	Reno flight demo in 2005. STRM and satellite imaging data only accurate enough for in-flight application, not take-off/landing and not world-wide. Need to add real-time data (i.e. weather, turbulence, in-flight/runway traffic)
Water Availability Forecasting (initially California and then the Western US)	Stephanie Granger, NASA, Tim Stough, NASA	Water managers are responsible for determining the amount of water that will be available in both the near- and long-term. RS and modeling can be used to inform hydrological parameters related to water use and forecasting precipitation.	The ideal situation would be to have an integrated measurement and modeling system linking measurements beginning with precipitation (to SWE) to runoff, storage, distribution, use and recycling or waste. Ability to forecast both precipitation and snow melt is important. Water supply mechanisms in the water budget are precipitation, snow, reservoir storage, and stream-flow. Improving the measurement and utilization of soil moisture in modeling runoff could help improve forecasts. Land-use and vegetation changes need to be monitored and archived since they contribute to both runoff behavior and irrigation requirements. The use of GIS to coordinate data products and integrate hydrography information is essential when processing is required to summarize parameters by elevation and/or watershed.	CA-DWR, USGS, LADWP and other water agencies	precipitation, snow pack, dust, land-use and vegetation changes, surface water, soil moisture, evapo-transpiration	Traceability to the following current and future missions: SMAP, HyspIRI, GPM, TRMM, MODIS, CRIS, VIRS, DESDynI, SWOT, LDCM

5.4 Spacecraft, Sensorwebs, and Networks

5.5 Sensorwebs, Onboard Processing, and Automated Workflows.

In this section we summarize the breakout discussion on the (potential) use of spacecraft autonomy, onboard processing, automated tasking, and automated workflows to increase the benefits of NASA assets for application users.

In our breakout we derived a number of use cases for a range of applications, highlighting the possible use of sensorweb and autonomy related concepts. Because these technologies are not broadly used today in operations these use cases should be considered realistic for the listed decadal survey missions, but not typical for current operations.

We also discussed a number of questions relating to the potential applicability of sensorweb technologies as driven by use cases. We discuss how automated tasking, automatic event tracking, automated product generation, and onboard processing relate to core issues of increasing NASA mission relevance to end application users.

In our breakout we had representation from a wide range of institutions including: USGS, universities, NASA Centers, NASA HQ and JPL, NWS, and DHS. The participants provided expertise in the following areas: software, high performance computing, environmental science, forestry, agriculture, disaster management, and earth sciences. The participants were well familiar with a range of missions and instruments, such as SMAP, NPOES, EOS, OMI, TOMS, and EO-1. While we did have sufficient end application user participation, broader participation by end users could have been beneficial. We also had a significant participant base who worked closely with application users particularly in the disaster response area.

5.5.1 Use Cases

As part of the workshop breakouts, the breakout participants developed five use cases for sensorweb and related technologies:

- Tracking a volcanic event (Redoubt volcano)
- Tracking a flooding event
- Tracking the station fire in southern California
- Vegetation plant stress/ drought
- Tracking a harmful Algal Bloom

These use case descriptions are included below. For each of these use cases we outline the steps in the application users use case and document how sensorweb technologies can assist in the application. We also list the relevant sensors and instruments applicable to the Decadal Survey Missions and highlighte their usages in the use case.

Use Case Name	Point(s) of Contact	Goal	Summary of the Scenario	Users (actors)	Key Systems Involved	Notes
Wildland fire	Provided by P. Campbell (NASA/GSFC); POC: HyspIRI SWG, S.Hook	Fire risk assessment, detect fire occurrence, estimate severity	1. Use spectral measurements of reflected solar radiation from the surface to determine land cover types, vegetation composition and moisture content to determine fire fuel availability and status. 2. Use thermal emissivity measurements to identify the presence of fires, measure the emitted radiation by small fires to determine their intensity.	Forest Service, Western States Wildfire Research and Applications Partnership (WRAP), Global Fire Monitoring Center (GFMC), GOFC-GOLD, NOAA Hazard Mapping System (HMS)	TBD - Currently: Land cover maps, Meteorological data, Airborne images, Satellite data (e.g. MODIS, EO-1 and other targeted observations),Fire Radiative Power (MODIS/VIIRS/GOES-R/GEOCAPE/HyspIRI), Fire detection (MODIS/VIIRS/GOES-R/GEOCAPE/HyspIRI)	
Drought	Provided by P. Campbell (NASA/GSFC); POCs: Son Nghiem, JPL and James Verdin USGS Sioux Falls	Drought detection:Forecasting, detection, monitoring, recovery/mitigation; implication for urban heat islands (UHI) assessment	1. National weather service reports lower than average precipitation weekly days outlooks of temperature, 2. Drought warning issued (used Palmer Drought Severity Index; for the US http://drought.unl.edu/; global forecasts http://www.cpc.ncep.noaa.gov/cgi-bin/gl_Soil-Moisture-Monthly.sh); Confirmation of event with low soil moisture, 3. Map Extend of event (TRIMM, MODIS and Ground networks "in situ data" and satellite (SMAP, LDCM, VIIRS, HyspIRI, SWOT) monitoring systems, airborne and satellite data. 4. Notifay USGS and local government, 5. Mitigation efforts and monitoring during the duration of the event	USDA, FAS, NGO (developing world), Commodities/food supply	US drought forcasts http://drought.unl.edu/; global forecasts http://www.cpc.ncep.noaa.gov/cgi-bin/gl_Soil-Moisture-Monthly.sh); satellite systems current and DS missions: TRIMM, MODIS; SMAP, LDCM, VIIRS, HyspIRI, SWOT.	Products – weekly drought forecast maps; DS Missions: SMAP – soil moisture, GPM– soil moisture, HyspIRI – vegetation type and moisture content, LDCM - land cover type
Wetlands	B huberty	wetland id and type with change over time	HyspIRI passes by (seasonally), indicating that crop species are stressed,	FWS, USACE, EPA, USDA, all states, tribes, ngo's and landowners	Current, better than 1m CIR spring imagery if available but need to incorporate Radar (INSAR) to map water level change in wetlands down to a couple inches (most feasible) as well as better forest wetland mapping.	
Habitat	B huberty	comprehensive habitat assessment for all species for every hour and every day.	very limited knowledge on full-scale habitat descriptions for all species.	FWS USACE, EPA, USDA, all states, tribes, ngo's and landowners	everything	

5.5.2 Facilitating Observations via automated tasking and cue-ing

How can sensor webs improve observation capabilities by allowing automated retasking to:

1. Increase temporal resolution of observations
2. Acquire complementary modalities (e.g. Electro optical, SAR)
3. Reduce response time of observations
4. Reduce effort of acquiring observation? How can integration of space asset tasking with ground instrumentation improve the effectiveness of spaceborne observation?

Future decadal missions are generally not taskable assets (e.g. they are nadir pointing and are always acquiring data when appropriate). DESDynI is a notable exception. In our use cases we identified several cases where the automated tasking of DESDynI would facilitate gathering of relevant application data. In the case of a flooding event, DESDynI could be automatically tasked to acquire L band SAR data to produce surface water extent maps. In the case of a volcanic event, DESDynI could be automatically tasked to provide INSAR data to provide inflation information (assuming existence of baseline data). In a volcanic event DESDynI could also provide L-band SAR data for surface cover information (snow, ice, land, lava, lahar).

5.5.3 Event Detection and Tracking

How can sensorwebs increase application users ability to detect and track events/phenomena of interest (esp. 24/7)

Numerous future decadal missions will directly support automated event detection as identified in our use cases. For example: HyspIRI TIR and VSWIR can be used for fire mapping and detection of volcanic activity; SMAP L band radar can be used to detect flooding and map surface water extent; DESDynI L band SAR can also be used to detect flooding via surface water extent as well as surface cover information (snow, ice, land lava, lahar).

5.5.4 Product Generation and automated workflows

How can automated workflows enable users:

1. To get products in the format and medium desired?
2. Enable easy evolution of products as needs change?

Automated workflows could apply in numerous places in our use cases. For example, surface water extent flooding products could be automatically delivered from SMAP and DESDynI radar products and HyspIRI VSWIR. HyspIRI VSWIR could be used to automatically deliver vegetation, canopy water content, burn scar, and snow/ice products.

5.5.5 Onboard Processing

How can onboard processing:

1. Decrease downlink requirements by producing quicklook and reduced data volume products and

2. Reduce product latency by allowing alternate downlink data streams (e.g. direct broadcast, S-band).

Our use cases identified two instances where onboard processing could alleviate problems of data volume for downlink and therefore facilitate rapid data delivery via alternate channels. On HyspIRI, onboard processing to detect thermal events of smaller spatial extent such as volcanic events and wildfires enables downlink of these products via heritage X band direct broadcast streams, decreasing significantly data latency. On DESDynI, onboard processing to detect events (such as surface water) can be used to produce much smaller data volume products such as surface water extent maps. These smaller products could be down-linked using faster data channels or instead of complete products.

5.5.6 Recommendations

The working group identified a number of areas of improvement to enable greater use of NASA data for applications. The developed use cases identified where sensorweb, onboard processing, sensor network, and retasking technologies could enhance NASA missions and improve these areas.

- Increasing the temporal resolution (e.g. more frequent re-visit time) would increase the use of NASA data in applications.
- Increasing the availability of data with multiple modalities (e.g. multispectral radar, high spectral resolution optical) would significantly increase the use of NASA data.
- The ability to subscribe to classes of data and be alerted for their availability would help significantly in using NASA data for applications.
- Delivering customized data products on demand (e.g. spatial subset, burn scar) would be beneficial.
- Automatic alerts to specific events (e.g. thermal alert, flood alert) would increase the usefulness of NASA data.
- Easy access/ability to perform basic processing on NASA data would increase application use.
- Decreasing the time from event to observation would significantly increase the use of NASA data for applications.
- Making available a sequence (in time since acquisition) of products of increasing quality would increase NASA application use.

6. Appendix A: Workshop Attendees

Conveners

Name	Affiliation	Area
Steve Volz	NASA Flight Sciences	Missions
Andrea Donnellan	NASA Applied Sciences	Natural Disasters
Karen Moe	NASA ESTO	Data Systems
Craig Dobson	NASA Research and Analysis	Partnerships

Organizing Committee

Name	Affiliation	Area
Simon Hook	JPL	ASTER/HyspIRI
Ann Marie Eldering	JPL	AIRS
Frank Lindsay	Goddard	Data systems
Steve Platnick	Goddard	EOS
Gerald Bawden	USGS	Applications
Bruce Davis	DHS	Applications
Chip Trepte	Langley	CALIPSO
Gary Jedlovic	Marshall	WEATHER
Ron Blom	JPL	DESDynI
Paul Rosen	JPL	DESDynI
Ed Sheffner	Ames	Applications
John Murray	Langley	Aviation/Public Health
Narendra Das	JPL	SMAP
Sue Estes	USRA/MSFC	Public Health
Michael Goodman	NASA Applied Sciences Natural Disasters	Natural Disasters

John Murray	NASA/LARC	Aviation Weather

User Panel

Name	Affiliation	Area
Bruce Quirk	USGS Land Remote Sensing	
Joe Dunbar	U.S. Army Engineer Research and Development Center	
Dave Johnson	NCAR Aviation Weather	
Jim Szykman	EPA	
Kim Richardson	NRL	
John Musinsky	Conservation International	
Nabeela Barbari	DHS Infrastructure Protection	
Jeanine Jones	California Department of Water Resources	

Mission Panel

Name	Affiliation	Area
Robert Wolfe	NASA GSFC	
Chip Trepte	NASA LARC	
Ed Sheffner	NASA ARC	
Gary Jedlovec	NASA MSFC	
Gerald Bawden	USGS	
Steve Chien	NASA JPL	
Shahid Habib	NASA GSFC	

Plenary Speakers

Name	Affiliation	Area
Jeff Morisette	USGS	Biodiversity

Jean-Pierre Bardet	University of Southern California	Civil Engineering

Breakout 1

Name	Affiliation	Area
Amor Ines	International Research Institute for Climate and Society	Agriculture
Ed Sheffner	NASA Ames	Agriculture
Ann Marie Eldering	NASA JPL	Air Quality
Ray hoff	NASA UMBC	Air Quality
Bruce Davis	DHS	Disasters
Shahid Habib	NASA GSFC	Disasters
Jeff Morisette	USGS	Ecological Forecasting
John Shnase	NASA GSFC	Ecological Forecasting
Dale Quattrochi	NASA MSFC	Public Health
Sue Estes	NASA USRA	Public Health
Jeanine Jones	California Department of Water Resources	Water Resources
Devon Galloway	USGS	Water Resources
Gary Jedlovec	NASA MSFC	Weather / Aviation
John Murray	NASA LARC	Weather / Aviation

Breakout 2

Name	Affiliation	Area
Robert Wolfe	NASA GSFC	Data processing systems
Michael Teague	NASA GSFC	Data processing systems
SiriJodha Khaisa	NSIDC	Geospatial information
Karl Benedict	UNM	Geospatial information

Pat Coronado	NASA GSFC	Ground data systems
Kevin Murphy	NASA ESDIS	Ground data systems
Steve Chien	NASA JPL	Spacecraft, sensorwebs, and networks
Petya Entcheva Campbell	NASA UMBC	Spacecraft, sensorwebs, and networks

Attendees

Name	Affiliation	Area
• Jassim Al-Saadi	NASA-LARC	Air Quality
• Vincent Ambrosia	California State University - Monterey Bay	Natural Disasters
• Valentine Anantharaj	Mississippi State University	Climate
• Leopold Andreoli	Northrop Grumman Aerospace	Climate
• Leslie Armstrong	U.S. Geological Survey	Climate
• Shyam Bajpai	NOAA/NESDIS/OSD	Weather/ Aviation
• Nabeela Barbari	DHS/NPPD/IP/IICD	Natural Disasters
• Jean-Pierre Bardet	University of Southern California	Water Resources
• Richard Barnisin	ATK Space Systems	Climate
• Larry Barone	NASA Ames/BAER Insitute	Ecological Forecasting
• Gerald Bawden	US Geological Survey	Natural Disasters

Name	Affiliation	Area
• Karl Benedict	Earth Data Analysis Center, University of New Mexico	Air Quality
• Andrew Bingham	JPL	Climate
• Ronald Blom	Jet Propulsion Laboratory	Natural Disasters
• Robert Brakenridge	Dartmouth Flood Observatory	Natural Disasters
• Kelvin Brentzel	Global Science and Technology	Natural Disasters
• Molly Brown	NASA Goddard Space Flight Center	Agriculture
• Amelia Budge	Earth Data Analysis Center, University of New Mexico	Public Health
• Philip Callahan	Jet Propulsion Lab	Climate
• Petya Campbell	NASA/GSFC JCET/UMBC	Ecological Forecasting
• Robert Chatfield	NASA Ames	Air Quality
• Jose Chavez	Colorado State University	Agriculture
• Fang Chen	GIS Training and Research Center, Idaho State University	Ecological Forecasting
• Steve Chien	Jet Propulsion Laboratory	Weather/ Aviation
• Lauren Childs	DEVELOP	Ecological Forecasting
• Marge Cole	NASA / SGT	Natural Disasters
• Rory Collins	Science Directorate	Climate
• Patrick Coronado	NASA	Natural Disasters
• Lucien Cox	NASA HQ	Climate

Name	Affiliation	Area
• Narendra Das	Jet Propulsion Lab	Water Resources
• Bruce Davis	Department of Homeland Security	Natural Disasters
• Alex de Sherbinin	CIESIN, Columbia University	Air Quality
• Bruce Doddridge	NASA Langley Research Center	Air Quality
• Andrea Donnellan	NASA	Natural Disasters
• Brad Doorn	NASA HQ	Agriculture
• Joshua Doubleday	Jet Propulsion Laboratory	Weather/ Aviation
• Mark Doubleday	Boeing	Ecological Forecasting
• Joseph Dunbar	ERDC	Water Resources
• Riley Duren	Jet Propulsion Laboratory	Climate
• Sanghamitra Dutta	NASA	Climate
• John Dwyer	USGS	Climate
• Annmarie Eldering	JPL/Caltech	Air Quality
• Sue Estes	NASA/USRA	Public Health
• Wayne Feltz	University of Wisconsin - SSEC/CIMSS	Weather/ Aviation
• Robert Ferraro	Jet Propulsion Laboratory	Climate
• Lawrence Friedl	NASA HQ	Air Quality
• Gregory Frost	NOAA/CIRES	Air Quality

Name	Affiliation	Area
• Kenneth Gage	Centers for Disease Control and Prevention	Public Health
• Devin Galloway	U.S. Geological Survey	Water Resources
• Paul Galloway	Teledyne Brown Engineering	Natural Disasters
• Maggi Glasscoe	Jet Propulsion Laboratory	Natural Disasters
• Michael Goodman	NASA/MSFC	Natural Disasters
• Stephanie Granger	Jet Propulsion Laboratory	Climate
• Shahid Habib	NASA	Water Resources
• Stephen Hagen	Applied Geosolutions	Agriculture
• Mary Ann Hall	Jet Propulsion Laboratory	Natural Disasters
• David Halpern	NASA HQ	Climate
• Mary Hayden	National Center for Atmospheric Research	Public Health
• John Haynes	NASA HQ	Public Health
• David Hermreck	NOAA/NESDIS	Climate
• Mr Roger W Heymann	NOAA-NESDIS	Water Resources
• Ray Hoff	University of Maryland, Baltimore County	Air Quality
• Simon Hook	NASA/JPL	Agriculture
• brian huberty	U.S. Fish & Wildlife Service	Water Resources

Name	Affiliation	Area
• Michael Hutt	USGS	Natural Disasters
• Amor VM Ines	IRI-Columbia University	Agriculture
• Scott Jackson	EPA	Air Quality
• Gary Jedlovec	NASA / MSFC / Earth Science Office	Weather/ Aviation
• David Johnson	National Center for Atmospheric Research	Weather/ Aviation
• Cathleen Jones	Jet Propulsion Laboratory	Natural Disasters
• Jeanine Jones	Calif Dept of Water Resources	Water Resources
• Said Kaki	Jet Propulsion Laboratory	Climate
• Ken Keiser	University of Alabama in Huntsville	Air Quality
• Steve Kempler	NASA - GES DISC	Air Quality
• SiriJodha Khalsa	National Snow and Ice Data Center/U. Colorado	Natural Disasters
• Si-Wan Kim	CIRES, U. of Colorado and ESRL, NOAA	Air Quality
• Robert Kudlinksi	Science Directorate	Air Quality
• Thomas P Kurosu	Harvard-Smithsonian Center for Astrophysics	Air Quality
• Francis Lindsay	NASA	Air Quality
• Jeffrey Luvall	NASA/MSFC	Public Health
• Tom Maiersperge	SGT/ EROS	Ecological Forecasting

Name r	Affiliation	Area
• Richard McNider	University of Alabama in Huntsville	Agriculture
• Brandie Mitchell	DEVELOP/SSAI	Ecological Forecasting
• KAREN MOE	NASA ESTO	Ecological Forecasting
• Andrew Monaghan	National Center for Atmospheric Research	Public Health
• Stanley Morain	Earth Data Analysis Center	Public Health
• Jeffrey Morisette	USGS Fort Collins Science Center	Ecological Forecasting
• rick mueller	USDA/NASS	Agriculture
• Kevin Murphy	NASA GSFC	Natural Disasters
• John Murray	NASA	Weather/ Aviation
• John Musinsky	Conservation International	Ecological Forecasting
• Doreen Neil	NASA	Air Quality
• Rodgerick Newhouse	Scitor	Climate
• Son Nghiem	Jet Propulsion Laboratory	Climate
• Charles Norton	NASA JPL / Caltech	Natural Disasters
• Gregory Osterman	Jet Propulsion Laboratory	Air Quality
• NIKUNJ OZA	TI, INTELLIGENT SYSTEMS DIVISION	Ecological Forecasting
• Craig Peterson	NASA-SSC	Air Quality

Name	Affiliation	Area
• John Petheram	Lockheed Martin Space Systems Company	Climate
• William Pichel	NOAA/NESDIS/STAR	Weather/ Aviation
• Kenneth Pickering	NASA Goddard Space Flight Center	Air Quality
• Fritz Policelli	NASA	Natural Disasters
• Dylan Powell	Lockheed Martin	Weather/ Aviation
• Dale Quattrochi	NASA	Public Health
• Bruce Quirk	USGS-DOI	Natural Disasters
• Vincent Realmuto	Jet Propulsion Laboratory	Natural Disasters
• Kim Richardson	NRL	Weather/ Aviation
• Doug Rickman	Applied Sciences/Marshall Space Flight Center	Climate
• Kenton Ross	SSAI	Agriculture
• Jesse Rozelle	FEMA Region VIII	Natural Disasters
• Suresh Kumar Santhana Vannan	ORNL	Ecological Forecasting
• Jeffrey Schmaltz	MODIS Rapid Response Team	Natural Disasters
• John Schnase	NASA Goddard Space Flight Center	Ecological Forecasting
• Paul Schramm, III	cdc	Public Health

Name	Affiliation	Area
• Brian Schwind	USDA Forest Service RSAC	Natural Disasters
• Edwin Sheffner	NASA/Ames	Agriculture
• Bill Sjoberg	NWS	Weather/ Aviation
• James Smoot	NASA/MSFC	Climate
• Michelle Sneed	US Geological Survey	Water Resources
• Tom Sohre	USGS	Ecological Forecasting
• Gary Spiers	Jet Propulsion Laboratory	Climate
• Margaret Srinivasan	Caltech/Jet Propulsion Laboratory	Climate
• Graeme Stephens	Colorado State University	Climate
• Timothy Stough	Jet Propulsion Laboratory	Water Resources
• James Szykman	USEPA Office of Research and Development	Air Quality
• Michael Teague	SigmaSpace	Natural Disasters
• David Tralli	Jet Propulsion Laboratory	Climate
• Chip Trepte	NASA LaRC	Climate
• Mark Tschudi	University of Colorado	Climate
• William Turner	NASA Headquarters	Ecological Forecasting
• Woody Turner	NASA HQ	Ecological Forecasting
• Stanley Underwood	Alliant Techsystems (ATK)	Climate

Name	Affiliation	Area
• Vern Vanderbilt	NASA/ARC	Agriculture
• Deborah Vane	JPL	Climate
• Stephen Volz	NASA	Climate
• Paula Wamsley	Ball Aerospace & Technologies Corp.	Climate
• Jennifer Willems	U.S. Geological Survey	Water Resources
• Robert Wolfe	NASA Goddard Space Flight Center	Agriculture
• Zhengwei Yang	USDA/NASS R Division	Agriculture
• David Young	NASA Langley Research Center	Climate
• Karen Yuen	NASA/JPL	Climate
• Emily Zielinski-Gutierrez	CDC/DVBID	Public Health

7. Appendix B: Workshop Breakout Sessions and Questions

Application objectives and needs within existing mission descriptions

What is the relevant application being discussed?

What are the goals and objectives that can be met by spaceborne measurements?

What missions address the goals and objectives of the application?

What are the observation needs?

How do these needs trace to the mission capabilities?

What are the needed data products?

What are the specific geographic targets?

What is the needed observation frequency and time period for the identified targets?

How quickly do the data products need to be disseminated?

Cross-Cutting Needs

Data Processing Systems

- What are the data products and levels needed to meet applications objectives? Requirements such as re-formatting or sub-setting should be included.
- How can applications be better addressed by data fusion?
- What improvements in data access are required to meet applications needs?

Spatio-temporal Information and Services

- What are the requirements for geo-referencing and co-registration of data?
- What data and information access and delivery requirements will meet your needs?
- What data processing and visualization tools are needed to meet applications needs? Do these tools exist or do some tools need to be developed?
- What geospatial standards (data formats, metadata, data services, etc.) are important to accomplishing your work?

Data Delivery Systems

- What is the needed data latency?
- What are the needs for direct broadcast? What are the needed downlink improvements to meet applications needs?
- How would near real-time data delivery on demand better address applications needs?

- What is the need for availability of instrument-specific science processing algorithms (Level-0 though Level-2 code) along with corresponding processing tools?

Spacecraft, Sensorwebs, and Networks

- What are the needs for acquiring new observation data on demand?
- What events or triggers should be considered to enable retargeting of sensors?
- How can applications be better served through onboard data processing?